AD A090120

LEVEL (12)

DNA 4795F

THEATER NUCLEAR FORCE SURVIVABILITY AND SECURITY INSTRUMENTATION

Study Phase

The BDM Corporation
1801 Randolph Road SE
Albuquerque, New Mexico 87106

30 November 1978

Final Report for Period 1 March 1978—30 November 1978

CONTRACT No. DNA 001-78-C-0194

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B390078465 A99QAXFC30201 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 18 DNA 4795F	2. GOVT ACCESSION NO.: AD-A090 120	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): 6 THEATER NUCLEAR FORCE SURVIVABILITY AND SECURITY INSTRUMENTATION, Study Phase.		5. TYPE OF REPORT & PERIOD COVERED: 9 Final Report, ~~for Period~~ 1 Mar 78—30 Nov 78
		6. PERFORMING ORG. REPORT NUMBER: 14 BDM/TAC-78-490-TR
7. AUTHOR(s): 10 T. E./Bullington, M. A./Ondrik, N./Hochhausler, H. J./Tausch, C. E./Wold		8. CONTRACT OR GRANT NUMBER(s): 15 DNA 001-78-C-0194
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The BDM Corporation, 1801 Randolph Road, SE, Albuquerque, New Mexico 87106		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 16 Subtask A99QAXFC302-01
11. CONTROLLING OFFICE NAME AND ADDRESS: Director, Defense Nuclear Agency, Washington, DC 20303 — 17 C302		12. REPORT DATE: 11 30 November 1978
		13. NUMBER OF PAGES: 152
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 152		15. SECURITY CLASS (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B390078465 A99QAXFC30201 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Theater Nuclear Force Survivability and Security
Force-on-Force
Free-Play
Real-Time Casualty Assessment
Micro-Processors

TNF SURVIVABILITY AND SECURITY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of the TNF S^2 instrumentation development whose purpose was to determine the optimum test instrumentation system. Evaluation of TNF S^2 technologies, hardware, and concepts requires field testing in both controlled test environments and simulated tactical environments. Free-play, force-on-force testing and real-time casualty assessment provide the two-sided, free-flowing operational scenarios necessary to determine successfully the resolution of the majority of the TNF S^2 issues.

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

391 884

1B

PREFACE

This report was prepared by The BDM Corporation, Technology Applications Center, 1801 Randolph Road, SE, Albuquerque, New Mexico 87106, under the Defense Nuclear Agency Contract Number DNA001-78-C-0194. Major L. A. Darda is the Contracting Officer's Representative.

This report presents the results of an extensive industry search and preliminary design for the optimum TNF S^2 test instrumentation.

Under this development effort an optimal set of TNF S^2 test instrumentation has been identified. This instrumentation is needed to satisfy the test analysis and evaluation requirements of force-on-force, free-play testing of the TNF using real-time casualty assessment. The instrumentation design philosophy centered around a system that is to be modular, flexible and expandable. The instrumentation will be portable, will not require extensive field support, and in some cases will be secure from outside monitoring. Existing, off-the-shelf technologies will be used to minimize development risk.

The instrumentation system will consist of three basic elements. The master station will perform the operation and maintenenace, calibration, test control and data quick-look tasks. The RF communications system will allow for two-way communications from the master station via repeaters to the players, and will evolve into an accurate transponder position location subsystem. The player instrumentation will contain a microcomputer and will be capable of totally decentralized ground operations. It will perform the functions of position location, weapon simulation (weapon and target sensors), player cueing, data logging, RF communications with the master station, and the computation of real-time casualty assessments.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

LIST OF TABLES

SECTION 1
EXECUTIVE SUMMARY

1-1 INTRODUCTION.

1-1.1 The Requirement for TNF S^2 Instrumentation.

The mock, free play, two-sided battle has long been used as a vehicle to test and evaluate new materials, doctrinal concepts, and organizational concepts. In such two-sided mock engagements, the realities of the battlefield need to be simulated so as to produce the best possible quasi-combat situation without endangering the lives of the participants. Objectivity in scoring engagement interactions is achieved by eliminating, whenever possible, subjective human judgments (and results) and by replacing them with real-time casualty assessments performed by computer algorithms based on accepted decision criteria.

Highly instrumented free-play, force-on-force operational testing has been conducted since 1971 by CDEC (Combat Development Experimental Command) at Fort Hunter-Liggett, TCATA (TRADOC Combined Arms Test Activity) at Fort Hood, TFWC (Tactical Fighter Weapons Center) at Nellis Air Force Base, and by OSD/TE (Office of the Secretary of Defense/Test and Evaluation) at numerous field locations. These organizations have demonstrated the usefulness of the quantitative data collected in force-on-force testing and have introduced instrumented testing as an important new discipline in the military planning process. The TNF S^2 (Theater Nuclear Force Survivability and Security) program deals with numerous aspects of the TNF (Theater Nuclear Force) planning process which can best be addressed using this new discipline to provide a realistic, quantitative characterization of military and terrorist operations which can affect the security and survivability of the TNF.

To enhance the survivability and security of the Theater Nuclear Force, technological, procedural, and operational improvements must be evaluated against a full spectrum of threats to determine the degree of enhancement each offers by itself and which they offer collectively.

Realistic, free-play, force-on-force testing can provide the following critically needed information for use in TNF planning:

1. Quantitative values to the numerous parameters which presently describe the TNF S^2.
2. A clear understanding of the detailed characteristics of the TNF S^2.
3. An augmentation and improvement of past and ongoing studies and analysis efforts which have an inadequate, limited data base.

The interaction of the various elements which form the basis of the TNF S^2 program is illustrated in Figure 1. The foundation of the program is a modern, flexible, and mobile test instrumentation capability. This system is necessary to address the greatly increased technological advancements of the threats and provides for more realistic simulation because it more closely approximates the actual engagement and combat.

1-1.2 Development Objectives and Approach.

The threefold objectives of this effort were to (1) determine the optimum TNF S^2 instrumentation system; develop the system requirements; identify, characterize, and evaluate candidate elements; define the integration tasks; and produce an instrumentation development plan; (2) develop specifications and acceptance procedures for the elements identified above; develop specifications for equipment purchase; and draft statements of work for equipment development, software engineering, and system integration; and (3) develop the plan for integration, evaluation, and test deployment.

The development methodology consisted of a total systems engineering approach utilizing feedback on an interative process. This technique allowed for a great deal of flexibility early in the program when the TNF S^2 issues and data requirements were not available but in their own cycle of definition and development.

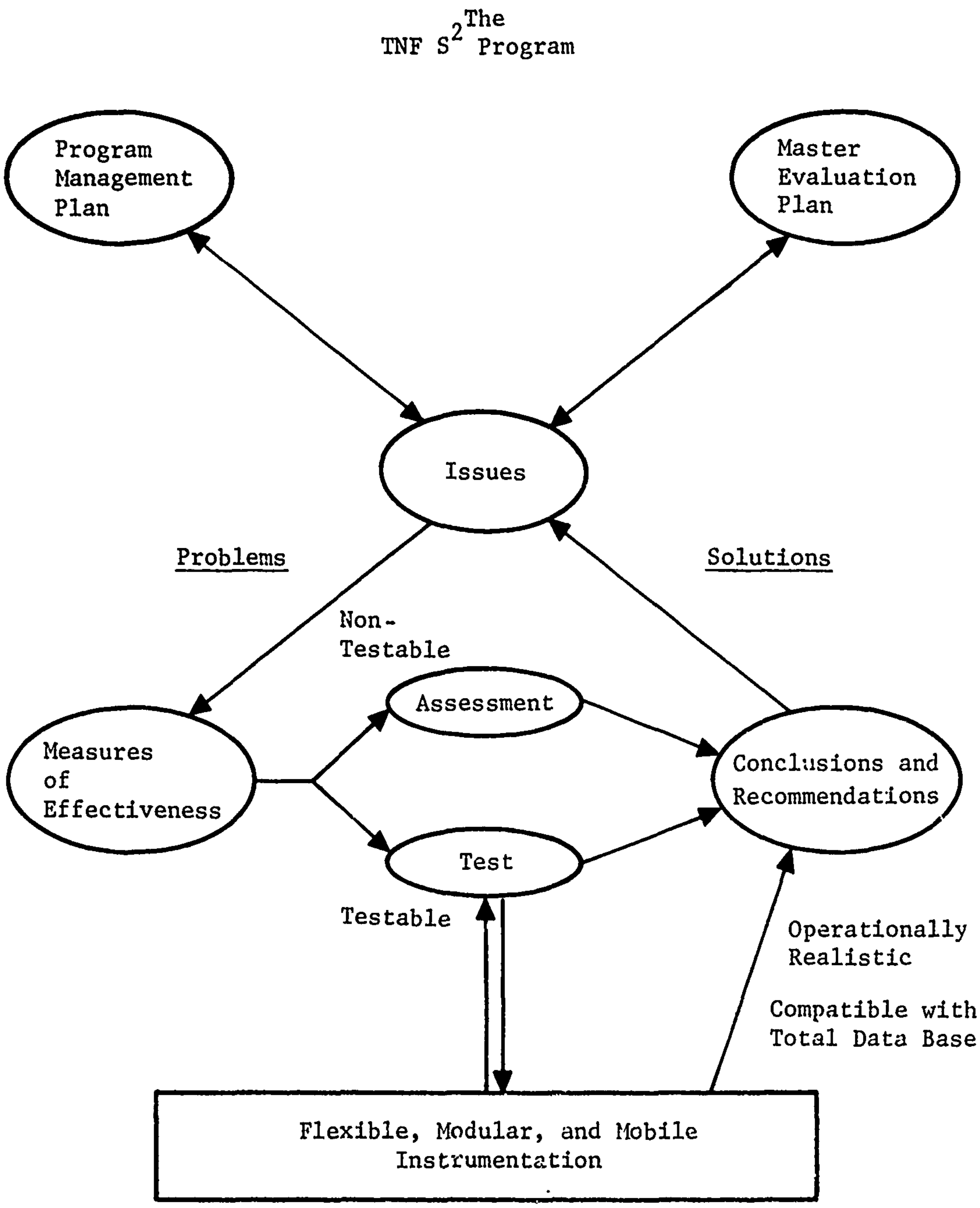


Figure 1. TNF S^2 program overview.

1-2 TNF S^2 DATA REQUIREMENTS.

1-2.1 Development of the Test Data Requirements.

The TNF issues, measures of effectiveness, and analysis methodologies were the key contributors to the development of the test data requirements and, in turn, the TNF S^2 instrumentation requirements. Examination of the early EUCOM issues indicated that the majority of the early TNF S^2 testing (FY 79-81) will focus on addressing generic nuclear weapon issues concerned with:

1. Storage Sites
2. Ground Movement
3. Air Base and Aircraft Storage Facilities
4. Unit and Equipment Signature

In turn, the relationship between the generic measures of effectiveness and test data requirements were assessed. Typical test data requirements for threat detection, suppressive fire, and exchange ratios are illustrated below:

MOE	DATA TYPE
Threat Position at Detection	Position Location/Movement
	Event Time/Recording
Suppression During:	
Uploading	Position Location/Movement
Staging	Weapons Effects
Deployment	Indirect Fire
	Real-Time Casualty Assessment
	Event Time/Recording
Exchange Ratio Variations for:	
Weapon Types	Position Location/Movement
Force Levels	Weapons Effects
Reaction Time	Indirect Fire
	Real-Time Casualty Assessment
	Event Time/Recording

To effectively identify the entire range of TNF S^2 data requirements, an umbrella approach was utilized. The spectrum of TNF S^2 scenarios was developed and each was examined. The following example illustrates the process utilized for developing a Lance security test data requirements:

1.	Test Objectives	- Estimate the value of remote sensors.
		- Evaluate security improvements in the consolidated battery positions.
2.	Test Method	- Computer Simulation
		- Force-on-Force Field Exercises
3.	Key Activity Areas	- Vehicle Upload and Removal
		- Transportation Choke Points
		- Convoy Assembly Area
		- Entrance Gate
		- Security/Threat Force Interactions
4.	Data Requirements	- Security Force/Threat Force
		- Position Location
		- Position Movement
		- Weapons Effects/Interactions
		- Indirect Fire
		- Real-time Casualty Assessment
		- Event Time/Recording
		- Chemical Monitoring (CBW)
		- Meterological Monitoring
		- Special Object Monitoring

1-2.2 Summary of the TNF S^2 Data/Instrumentation Requirements.

Evaluation of the scenarios, coupled with the evolving issues, provide the source for the following instrumentation guidelines:

1. The number of players (to include fixed objects) is typically 30 to 50, with an occasional requirement of 100.

2. The typical playing area is several hundred meters (300 by 300 meters), with a maximum area of 2 by 2 kilometers. The convoy exercise will require a longer but narrower playing area.
3. Most scenarios have elements of close-in interactions involving participants at 3 to 10 meters.
4. The weapons systems employed are primarily portable by man or light vehicle.
5. The instrumentation must function both in day and night operations in adverse weather, and over hilly and forested terrain.

The data requirements developed for TNF S^2 testing are summarized in Table 1. This table presents the type of data, the required/desired accuracy, and the instrumentation system which provides the necessary information.

1-2.3 Limitations of Fielded Instrumentation.

The force-on-force test instrumentation which is presently being utilized is first-generation equipment and was designed in the 1960's prior to the existence of well-proven, large-scale integrated circuitry. The operational and design characteristics, therefore, reflect the capabilities and limitations of the then-available technology. Many of the previously accepted operating procedures and instrumentation technologies are now considered as severe limitations.

Today's force-on-force instrumentation has the following limitations:

1. Catastrophic Failure Modes
2. Complex Software
3. Telemetry Dependent
4. Resource Intensive
5. Limited Mobility

The equipment currently fielded, in all cases, is completely dependent upon a central computer system which tracks all of the players and scores all of the engagements. Consequently, a central computer

Table 1. TNF S^2 data requirements.

Player Position	Data Type Requirement/Accuracy	Instrumentation System
Deployment Analysis	15 to 25 m	Position Location Candidates
Movement Analysis	5 to 10 m	DME - Direct Range Measurement Multi-Instrumentation
Tactics Analysis	2 to 5 m	TDOA - Time Difference of Arrival
Decision Criterion Analysis	2 to 5 m	Radar - Range/Angle
Indirect Fire	2 to 5 m	Initial - Onboard Guidance
Real-Time Casualty Assessment	2 to 5 m	Accurate Position Location Player-to-Player Direct Ranging Sensor Hit Pattern Recognition Probability of Kill Calculation Player Cueing
Line-of-Sight Weapon/Target Pairing	Pairings to 2 km with No Anomalies	Laser Transmitter Laser Sensors Player Cueing
Indirect Fire Simulation and Hand Grenade/Explosives	3 to 5 m	Radio Link to Players Flash/Bang Simulator Accurate Player Position Player Cueing
Detailed Engagement Information	1 to 3 m	Audio and Video Recorders
Quick-Look Data	1 to 4 Hours After Exercise	Mobile Computer
Test Initiation/Control	Pretest/Test/Posttest	O&M Capability in the Field
Data Logging	Up to 10 Hours	Onboard Bulk Storage RF Link to O&M Facility

failure or malfunction is catastrophic - the entire exercise must be halted and be reinitiated after the failure is corrected. In order that all of the required data be available at the central computer location, it is necessary that a telemetry link be operational at all times. Failure of the telemetry link is as catastrophic as a computer failure. In support of the large central computer is an equally large and complex software package, which is costly and difficult to maintain. The human resources required to operate and maintain the computer, the software, the telemetry system, and the other instrumentation elements of the system are also quite large - and in some cases larger than the forces involved in the test.

A final consequence of the present instrumentation is that all tests are performed where the equipment is in place. The existing instrumentation is transportable, but by no means mobile; therefore, tests are few and typically very expensive.

New emerging technology will permit the TNF S^2 instrumentation system to overcome these limitations.

1-3 THE TNF S^2 INSTRUMENTATION SYSTEM OVERVIEW.

1-3.1 Background.

The recent availability of large-scale integrated devices and the ability to produce microcomputers of high sophistication using few components allows the design of an instrumentation system which eliminates the problems associated with the presently fielded equipments. Admittedly, the new technology has its own set of problems, but they are relatively minor in comparison.

With today's microprocessors and large-scale integration technologies, it is now possible to develop a highly modular set of force-on-force instrumentation, based on the premise that each player carries his own computer with functional subsystems supplied on an as-needed basis. The system architecture takes the form of "plug-in" modules which interface to the computer through a standard peripheral buss. This modular concept, coupled with the standard interface, allows future improvements (e.g., addition of GPS/NAVSTAR for position location) to be incorporated with no adverse impact on the other system elements.

The central computer system can be reduced to a single, easily maintained minicomputer, or it can be eliminated, because each player is independent and can perform all the necessary calculations for tracking his position and scoring weapons engagements. This concept in and of itself eliminates the catastrophic system failure modes seen in earlier systems. It also greatly reduces the manpower requirements of operations and maintenance. The software required by each player is relatively straightforward and event-driven (external inputs).

From the above, it can be seen that position location, data acquisition, data processing, and recording can now be done on compact instrumentation located on individual players. The existing technologies have reached the stage of development where it is possible to develop, with low risk, a simple, decentralized instrumentation system which has the following features:

1.	Modularity	- The addition of players does not require re-engineering or major software reconfigurations.
2.	Mobility	- It will be practical to test at training sites throughout the United States and in Europe.
3.	Graceful Degradation	- The system fails player-by-player.
4.	Reduced Support	- It requires a minimum of orchestration during set-up for each trial.
5.	Directly Convertible to Training	- The use for training will be a subset of the total capability.

1-3.2 System Design Philosophy.

It is now possible to develop, utilizing a highly modular approach, force-on-force test instrumentation based on the premise that each player carries his own computer.

The computer is a high performance, versatile, general-purpose process controller (a process may be software [a calculation] or hardware [a response signal]). Processes are initiated by stimuli from the player's external environment. Two examples of such stimuli are position location signals and weapon simulator laser signals. The processes which can be initiated are determined by the computer's ability to sense these external stimuli. Depending upon a player's role in a given scenario, he may or may not require access to all available external signals. Consequently, the hardware which provides access to these stimuli (e.g., radio receivers, laser sensors, etc.) is conceived in the form of "plug in" modules which interface to the computer via a standard peripheral buss. Modules are provided to a player on an as-needed basis, dependent upon his function in a particular scenario.

The modular concept coupled with the standard interface allows future improvements in technology to be incorporated with no adverse impact on the remainder of the system.

Since the player-carried computer performs all the calculations for tracking position and scoring engagements, the massive central computer is reduced to either a single minicomputer or none at all. Elimination of the large central computer in and of itself implies that the system has no catastrophic failure modes - it degrades gracefully, player by player, if at all. It further implies, by virtue of size alone, that the system is inherently mobile. Since a great many of the support personnel requirements of a conventional system are linked to operation of the central computer, those too are eliminated. Furthermore, the software required by each player computer is fundamentally simple - it need only perform computations involving a single player.

Thus, the concepts of modularity and distributed intelligence allow for design of a system which is highly flexible and mobile, eliminates the serious shortcomings of existing equipment, and adapts easily to changes in requirements or technology.

The use of modular instrumentation is somewhat different from standard approaches to testing. One must examine the issue at hand to determine the scenario involved (i.e., force-on-force, procedural, time motion, etc.). Having done this, one must determine what data are required for analysis (i.e., position, real-time casualty assessment, etc., and in some cases the accuracy or precision required). Finally, any unique requirements must be determined (i.e., weather monitoring, toxic gas monitors, etc.). This process determines the overall functional requirements of the instrumentation system as a whole. Using the modules available, one then very quickly builds a system that meets those requirements.

The modularity of the instrumentation manifests itself at two levels. First, one builds a system from the three modular subsystems depicted in Figure 2. These are the master station, the player packs, and the communications system. At the second level, each of the subsystems selected is further customized by the addition of functional hardware modules.

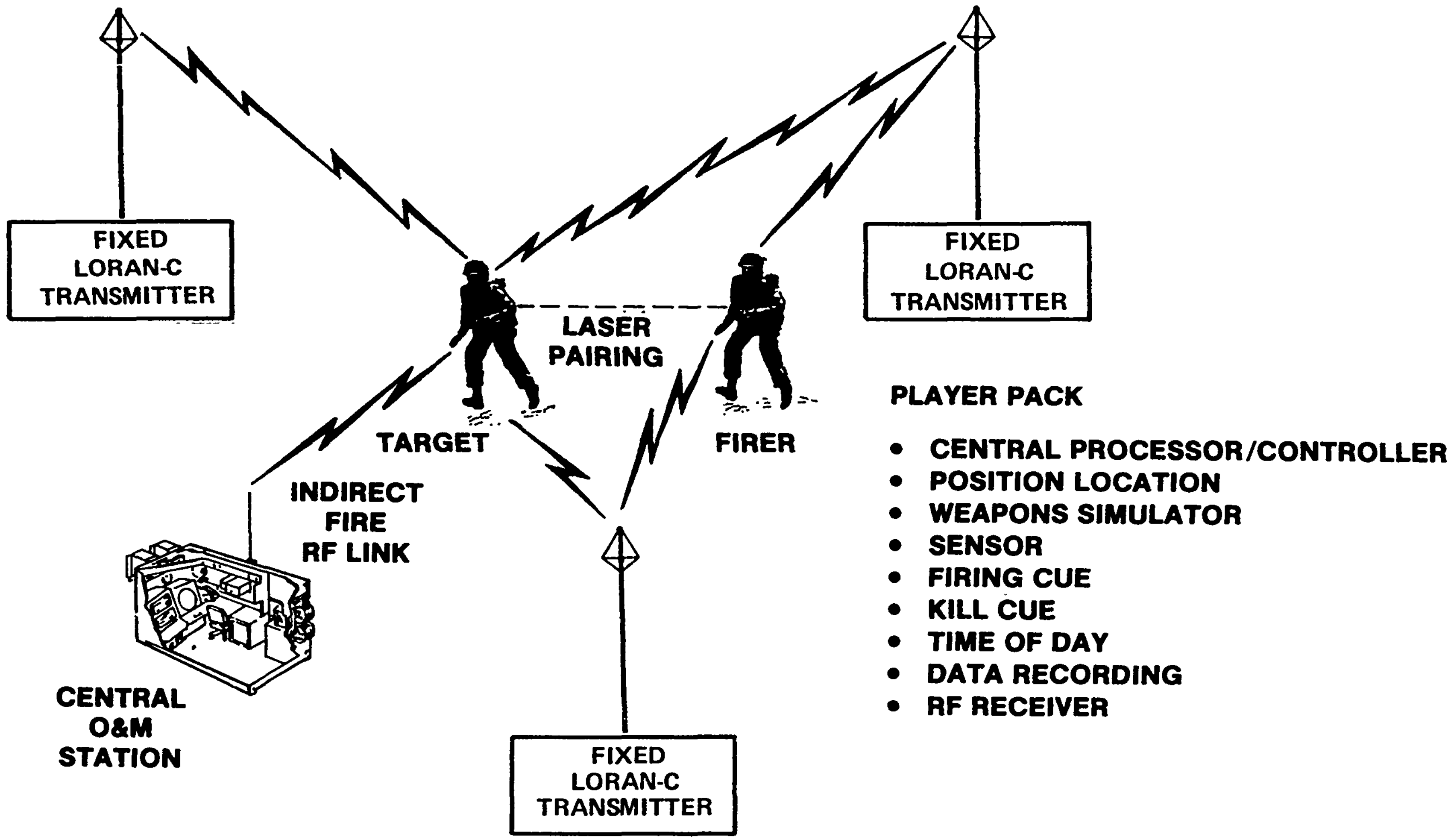


Figure 2. LORAN-C decentralized system.

1-3.2.1 Master Station. The master station is designed to serve a wide variety of functions. It is a multi-user configuration and so can perform several tasks simultaneously. Even though it has this capability, it is quite small, with the computer itself occupying only a single equipment rack.

The operations and maintenance function is available concurrently with all other functions. It consists primarily of calibration and functional testing of the player packs and the communications link (if used). In this role it is anticipated that sufficient software is made available so that the technician performing those duties need only type a command to "test" and wait for an indicator to signify "good/bad." This allows maintenance to be done by a less highly skilled individual than might otherwise be the case.

During pretest, the master station will supply the player packs with test and test-site specific constants, such as the coordinates of transponders, and provide for a field calibration operation. An example of a field calibration operation might be for the player to stand on a pressure switch and fire his laser weapon simulator at a specific target. He would in turn be fired upon by an emplaced laser. Both the player and the target must score a hit and indicate certain predetermined scoring data.

With the communications system in use, the master station can control test timing, start and end of testing, all data traffic, transmit simulated indirect fire data, and, if required, collect stored information from the players to generate a real-time display of player activity.

In the quick-look analysis mode, the master station debriefs the player packs and validates the data structures. It further compares the player data against the test MOE's for immediate in-field test validation (at this point the test may be re-played if necessary without total re-deployment). Finally, it produces a merged test time-line tape for use in detailed test analysis.

1-3.2.2 Player Pack. A player is any individual or object which is instrumented with a TNF S^2 player pack. Examples are: humans, vehicles, doors, weather stations, gas sensors, television cameras, bombs, etc.

Since each player carries his own computer, he functions autonomously. A player's "signature" or functional identity is determined by the module set he carries. Thus, while a human very likely carries a weapon simulator module, a door or weather station most probably does not.

The primary element of any player is of course the player pack, shown pictorially in Figure 3. Without a player pack, the individual in question does not exist as far as test control elements are concerned. His position cannot be tracked and he cannot score or be scored upon by other players.

The player pack itself consists of a fixed part called the executive control system (ECS), and a variable part consisting of the particular mix of functional modules (i.e., the player's unique identity). Every player pack contains the ECS, consisting of the microcomputer, the battery pack, the chassis, and the peripheral buss.

The ECS microcomputer consists of a microprocessor, an interrupt controller, the requisite clock generation circuitry, memory and memory decoders, and peripheral buss drivers.

The peripheral buss carries the necessary control signals to all of the functional modules. All the peripheral buss connectors are identical; consequently, any module can be plugged in at any point on the buss. Use of a standard common interface greatly reduces the cost and development time of new hardware and the associated software.

Software for ECS is generically separable into two classes - control codes and computational codes. The control codes have all the features of a prioritized, interrupt-driven, multi-tasking operating system.

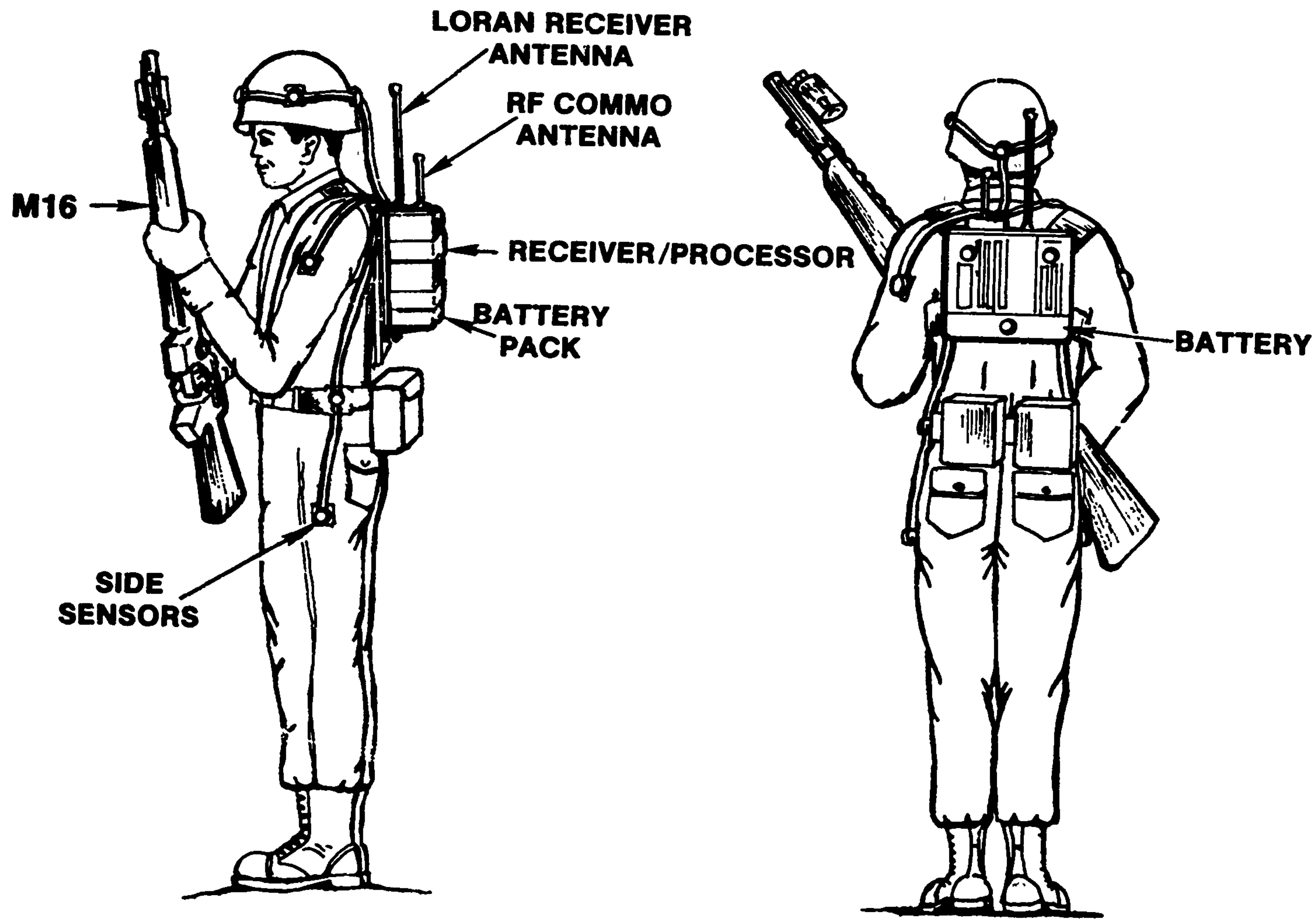


Figure 3. Conceptual manpack configuration.

Running under control of ECS are the computational codes or tasks, where all the real work is done. Examples of tasks are: PL (position location) computation, RTCA (real-time casualty assessment), and message validation. Tasks are activated as required by incoming data on a priority basis which reflects their overall importance. For example, an RTCA task is more important than a PL task, since it determines the player's fate. Because of the tasking structure of ECS, task function can be modified to reflect specific test requirements or unique situations without altering the ECS control codes.

1-3.2.3 Communications System. The RF communications system has been developed to provide two-way communication between the master station and the individual players. In the communications mode, the master station initiates all requests for player data and acts as a central test controller. This feature can be deactivated at the master station with no degradation to the other system functions.

The major elements will include (1) a transmitter/receiver, logic control, and minicomputer interface at the master; (2) a repeater transponder with logic control at the repeater stations; and (3) a receiver/ transmitter and logic control on each player.

The RF communications system will be developed utilizing identical units at the master and repeater, with miniaturized transceivers on the players. The pulse position scheme will be identical to the laser/ weapons effects subsystem and will utilize identical hardware.

1-3.2.4 TNF S^2 Instrumentation Summary. Each of the subsystems contains a fixed core of electronics analogues to a multi-process controller; the modules incorporated then determine what the various control processes are and when they are activated. In order to maintain flexibility, provide for rapid system-building, and allow for future growth, the core of each subsystem must meet the following objectives:

Capacity - It must have the capacity to handle additional loading generated by future requirements.

Expandibility - It must be easily expanded to incorporate new functional modules.

Flexibility - It must easily incorporate improvements to existing modules.

Adaptability - It must adapt easily to new or nonstandard uses of existing modules.

Independence - It must operate properly independent of the particular mix of modules implemented.

Likewise, the modules available to each subsystem must meet an additional set of objectives:

Common Interface - They must all utilize a standard common interface in order to simplify both the buss structure and the software protocols.

Independence - Proper operation of a module must not depend on the presence of another module (unless its purpose is to enhance the capabilities of that module). Use of a module should not preclude the use of other modules.

1-4 INSTRUMENTATION DEVELOPMENT SYSTEM.

The instrumentation development system is a multipurpose, multiuser engineering tool to be used in the development of both hardware and software for all three of the TNF S^2 instrumentation subsystems and potentially for the detailed test analysis task. It is configured to have the capability of serving in four modes: (1) multiuser development system for the player-pack electronics, (2) quick-look and master station development, (3) fieldable master station, and (4) detailed test data analysis processor.

Such a system is critically necessary for player-pack development. High-performance microcomputers such as ECS are very complex, sequential, and combinatorial logic networks. Their characteristics and critical paths are well-known but nontrivial. The development system provides the means to emulate the behavior of the entire system under development. Without such a development tool, microprocessor-controlled equipment can be expected to contain many "hidden" catastrophic logic paths which become evident only after the equipment is fielded. Often these problems occur only under conditions which never arise in the engineering laboratory.

Since the master station and the development system are essentially the same equipment, many of the procedures and special test equipments produced during the player pack development phase can be transferred directly to the field operations and maintenance facility.

The commonality of the master station and the instrumentation development system also allows quick-look and detailed test analysis software development to proceed in parallel with the hardware development using the same development system.

Because the instrumentation development system is common to so many phases of the overall TNF S^2 test capability development, and because it is critically necessary for hardware development, it must be considered an early acquisition item.

1-5 INSTRUMENTATION DEVELOPMENT APPROACH.

The development approach for the fielding of the TNF S^2 instrumentation has been driven by two factors. First, initial evaluation of the EUCOM issues indicates a high-priority need for early testing of the TNF. The proposed field test schedule indicates a need for a full instrumentation capability in late FY 1980. A fully instrumented test is one which requires the following data: position location, position movement, weapons effects, real-time casualty assessment, and event timing and recording. Back-to-back tests of issues concerning storage sites, ground movements (convoys), and unit and equipment signatures are presently planned for FY 1981. Simultaneous testing is planned for late FY 1981 in issues addressing field storage locations and nuclear unit security.

The second factor is the desire to utilize off-the-shelf components to the greatest extent possible. This is desirable to reduce the overall development risk in both cost and schedule.

To meet these somewhat opposing desires, an incremental approach to the development was chosen. This approach will field a prototype system of 15 players in the third quarter of FY 1980. The prototype system provides all the features of the field instrumentation system. It will be based on LORAN-C, and it will allow for a medium resolution early test capability of 15 to 20 meters. Packaging of the prototype system may not be optimum; however, it will allow for a full test capability.

Following the prototype system will be a complete 50-player instrumentation module based on LORAN-C, scheduled for availability during the second quarter of FY 1981.

Two parallel development efforts are presently planned. The first will consist of the transponder position location subsystem. This effort will be initiated at a relatively low level of effort in FY 1979 and will follow the LORAN-C variations by approximately 6 to 8 months. This system can directly replace the LORAN-C receiver and will utilize the existing RF communications link. The second effort involves the determination of requirements for simulation systems. This effort will be initiated in FY 1979 and will consist of an industry search and specification development for future simulation devices.

The TNF S^2 instrumentation, as presently conceived, will be developed around a modular/functional basis to allow maximum flexibility. Throughout the life of the instrumentation, it will be incrementally enhanced and its capability expanded to meet new and unforeseen issues.

Table 2 shows several of the key developement milestones. Note that the schedule is contingent upon receipt of the GFE instrumentation development system and other required government-furnished equipment, as described in Appendix B.

Table 2. Key development milestones.

Item	Description	Date	Source	Comments
1.	Instrumentation Development System (IDS)	Month 3.5	GFE	Delay Past Month 3.5 Will Cause Commensurate Schedule Slip
	Hardware/Software Development			
2.	Functional Demonstrations	IDS + 6-9 Months		Lab Demonstrations of Functional Brassboards - Not Packaged
	Executive Control System		CFE	ECS Computer Brassboard Demo
	Radio Communication System		CFE/GFE	
	Weapon Effects System		CFE/GFE	Requires GFE Laser Brassboard and Components
	LORAN Position Location		CFG/GFE	Performed Where LORAN-C Chain Exists
3.	Transponder Position Location	Mid-FY81	CFE/GFE	Accurate PL System. Add-On to Commo.
4.	Field Evaluation (FE)	IDS + 12-15 Months	CFE/GFE	3-Unit System Demo. Schedule Dependent on Receipt of IDS
5.	Prototype IOC Modified Units	FE + 4 Months	CFE/GFE	Field Evaluation Modification Applied to Prototypes
6.	Production IOC Production Units	MID-FY81	GFE/CFE	First Production Units Ready for Use

SECTION 2
SYSTEM FUNCTIONAL DESCRIPTIONS

2-1 INTRODUCTION.

The functional characteristics of the three major TNF S^2 instrumentation subsystems have been described generically in the previous chapter. While the design details of these components are not available (the detailed design is a FY 79 effort), this chapter provides their preliminary descriptions and points out the details which must be considered in their final design.

2-1.1 Master Station.

The master station provides the field instrumentation with operations and maintenance support, pretest initialization of player packs, test control (if the radio communications subsystem is used), post-test data collection, and quick-look analysis capability.

2-1.1.1 Operations and Maintenance. This phase of the operation involves verification of the proper operation of all player packs and subsystems (communications, position location, etc.). Inoperative modules can be detected and replaced, batteries charged/replaced, and weapon simulators bore-sighted and verified. The bulk of the hardware and software for the O&M phase of testing will be produced as a natural part of the player pack development and transported intact from the instrumentation development system.

2-1.1.2 Pretest Initialization. This phase of the operation uses much of the same equipment as the O&M process. It begins just prior to actual testing and involves down-loading software to the player packs, synchronizing their time-of-day clocks, providing test and test-site specific constants (such as transponder coordinates), and final verification of all player systems.

2-1.1.3 Test Control. When the RF subsystem is used, the master station can coordinate the test. It will issue "start test" commands and control RF message traffic. If the transponder position location subsystem is utilized, the master station will control the system timing by issuing "start PL" commands. Software simulated indirect fire will originate from the master station. Finally, the master station will issue a "stop test" and/or a "recall."

Potential future growth items already identified include:

1. Test "Snapshots"

   During a long test, player position and status can be requested and recorded at the master station. Quick-look or real-time monitoring of MOE's can occur during the test to make sure all aspects of the test are running properly (i.e., no instrumentation failures, critical-player status checks, percent of players killed, etc.). This can prevent a long test from running to completion before an early failure is recognized and corrected.

2. Real-Time Display

   All player data could be recorded at the master station and used to produce a real-time display of player position, weapon engagements, and total system status.

2-1.1.4 Posttest Data Collection. During this phase of the test, all the player data is collected, recorded, and validated. A merged test time-tape is produced for quick-look and later detailed analysis. The master station provides this capability either through the RF communication system or by direct connection to the player pack.

2-1.1.5 Quick-Look. After the test is complete, the data is checked against the MOE's and other measures of test validation. If necessary, a test can be repeated at this point while all the equipment and personnel are still deployed. This process requires the master station to have somewhat greater memory and mass storage capacities than any of its other functions.

2-1.2 Radio Communication Subsystem.

2-1.2.1 Subsystem Functions. The RF communication subsystem will provide two-way communications between a central control facility and various system players. Further, this subsystem will be designed so that, in conjunction with other subsystems, it will form a major part of a transponder position location system. The subsystem consists of two major elements: the receiver/transmitter units and the repeater/transponder stations. Details of these functions are given below.

2-1.2.2 Two-Way Communications. All communications in the system will be handled through a master station, which will initiate all communications with either a single player or group of players. Any given player will only transmit information when it has been requested by the master station. A list of potential communications traffic is shown in Table 3.

It should be noted that some aspects of the system application dictate how various components of the system are implemented. For instance, the system must communicate bidirectionally, and since the player units must be man-portable, this sets a practical limit on the size of the antenna. This in turn restricts the RF communications frequency to greater than 400 MHz. At this frequency, RF transmission is basically line-of-sight. Therefore, the system must include repeater stations to insure adequate coverage (Figure 4). Also, since the attitude of a player's antennae with respect to the master station antenna may vary (prone versus standing), at least one of the antennae must be circularly polarized.

Another constraint which derives from the man-portable aspect of the system is total power consumption. This must be minimized, but the peak radiated power from each player must be maximized. Therefore, a pulse type of RF transmission is desirable. Since the recovery times and maximum duty cycles of standard RF pulse generators are very similar to those of the lasers used in the weapons simulator subsystem, it is advantageous to use the same pulse positioning scheme for data encoding in both subsystems. This allows a high degree of commonality between the

Table 3. Radio communication messages.

	Message Type	Direction	Destination	Comments
1.	Start Test	MS → P	All Players	Signals ECS to go to "TEST" mode
2.	Stop Test	MS → P	All Players	Signals ECS to go to "posttest" mode
3.	Request Position	MS → P	Specific Player	Addressed player transmits his position
4.	Request Status	MS → P	Specific Player	Addressed player transmits his status
5.	Request Logged Data	MS → P	Specific Player	Initiates data unloading
6.	Repeat Previous Message	MS ↔ P	Specific Player	
7.	Message Received	MS ↔ P	Specific Player	Indicates receipt of valid message
8.	Begin PL	MS → P	All Players	Initiates PL cycle
9.	IDF	MS → P	All Players	Indirect fire simulator (impact point)
10.	Request IAVS	P → MS	Specific Player	Waits for "open channel", requests shielding status
11.	Respond IAVS	MS → P	Specific Player	MS supplies shielding status
12.	Channel Open	MS → P	Specific Player	Enables player to transmit any desired message to MS (i.e., #10)

MS - Master Station
P - Player
IAVS - Immediate available vertical shielding

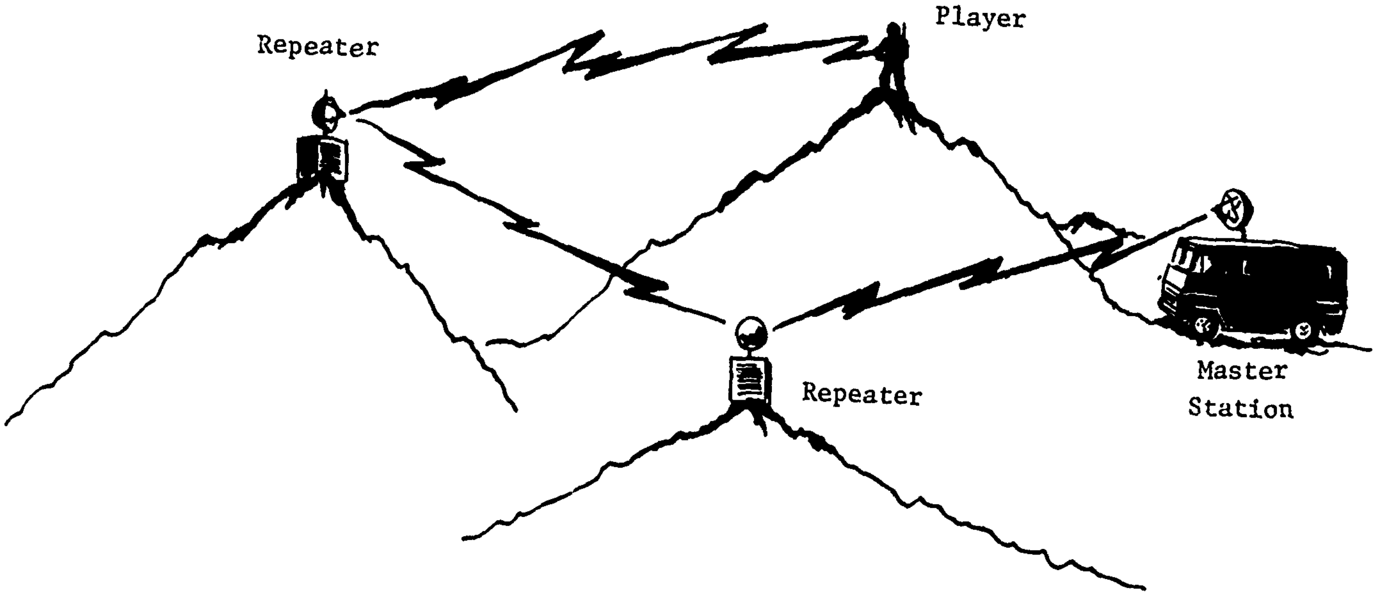


Figure 4. The RF communication subsystem will be comprised of a master station, repeaters, and player units.

two systems and, indeed, the same data encoding/decoding hardware and software can be used. Therefore, the only hardware development which will be required for the RF communications subsystem is for those elements which deal directly with the RF signals - that is to say, the actual RF antenna, the pulse transmitter, and the pulse receiver.

The only difference in data encoding between the RF communications subsystem and the laser weapons subsystem will be the way in which data validation is done. In the laser weapon system, data validation will be done by transmitting the same message several times and doing a "majority vote" check at the receiver for errors. Data validation in the RF communication system, however, will be done by appending two cyclic redundancy-check bytes to the end of each transmitted RF message. This will allow a single transmission of data to be adequately verified at the receiver.

One potential problem when using position encoding with an RF communications system is multipath. This problem can be illustrated by considering a player close to the master station. Such a player would receive a valid data pulse from the master station immediately after it was broadcast. That same pulse could be transmitted across the playing area, echoed at a repeater station, and again picked up by the same player. If the possibility of multiple-pulse reception is not accounted for, then the player would interpret the two pulses as valid data, resulting in an erroneous message. For this system, all repeaters will be within a 5 kilometer square area, and this problem will be overcome by locking out both the player receiver and the repeater station for 20 μs after every pulse (Figure 5). Thus, every time a repeater station receives an incoming pulse, it will immediately transmit an RF pulse and lock out its receiver for 20 μs until pulses generated by reflections or other repeater stations have subsided. Similarly, a player will listen for a single pulse and ignore all subsequent pulses for 20 μs.

The timing for pulse generation will be the same as in the weapon simulator subsystem. Thus, a 72-bit message will be completed in a maximum of 3 ms. This yields a data transmission bandwidth of at least

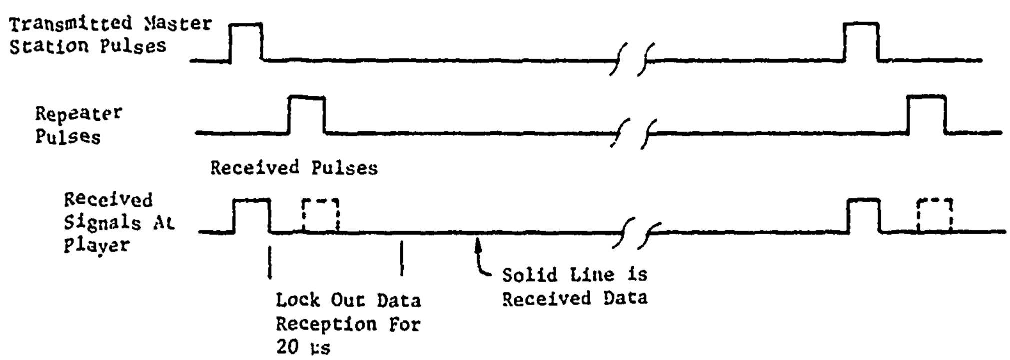


Figure 5. Multipath errors will be eliminated by locking out data reception for 20 μs after every pulse.

24,000 bits per second (actual bandwidths will be higher, since message transmission time will vary with information content).

2-1.2.3 Transponder Position Location. As presently envisioned, the RF communications system will provide the basis for a transponder position location system. The details of how this will be done are discussed in Section 2-2.1.3. However, the aspects of importance here are that the repeater stations will double as transponders, and the individual players will be able to measure round-trip times of RF pulses to the various transponders. This influences how various hardware elements are designed.

2-1.2.4 Hardware Elements. As has already been discussed, there will be three functional elements to the communication system. These are the master station, the repeaters, and the players. The functions which each of these elements will perform are very similar and, in fact, can be implemented using common hardware elements. The elements which will be used for both the master station and the players will be an antenna, a pulse receiver/transmitter, and a digital interface which will communicate to either a player's ECS or the master station's minicomputer. The hardware elements for a repeater will be only an antenna and a pulse receiver/transmitter.

Other factors influencing the design of the hardware are the transmitted RF power and the receiver sensitivity. From power and weight considerations, the RF power transmitted by a player must be minimized. However, the transmitted power and the receiver sensitivity on the master station and on the repeater station can both be optimized.

The figure of merit for performance of an RF link is a combination of transmitted power and receiver sensitivity. With this in mind, the player elements will transmit at low power, and the receiver on the repeaters/master station will be very sensitive. Similarly, the master station and repeaters will transmit at a correspondingly greater power, and the players will have a less sensitive receiver. Therefore, the power/receiver sensitivity combination will be similar in both directions (player-repeater, repeater-player).

Consequently, four hardware elements will comprise the RF communications subsystem. There will be two types of RF receiver/ transmitters, one for use on the player, and the second to be used on both the master station and the repeaters. The other two elements will be the antenna and the digital communications interface. The description of these hardware elements is given below.

2-1.2.5 Receiver/Transmitter. There will be two types of receiver/ transmitter modules for this system. The primary difference between the two modules will be transmitter power and receiver sensitivity. All connections to the two types of receiver/transmitters will be identical.

The first receiver/transmitter will have a nominal receiver sensitivity of approximately -83 dbm, and will transmit RF pulses with a peak power of approximately 800 watts. This type of receiver/transmitter will be used in both the master station and the repeater unit.

This receiver/transmitter will be designed such that it can operate in two modes. The first mode will be normal receive and transmit, and the second mode will be transponder. In the normal mode, a received RF pulse will cause an output TTL (transistor-transistor logic) digital signal to be passed on to decoding electronics, and the digital control input will then cause a single RF pulse to be transmitted. When in the transponder mode, the unit will transmit an RF pulse immediately upon recognition of its ID code and will ignore all incoming signals for a period of 20 μs. The received RF pulse will also be output as a TTL signal. The selection of the mode of operation will be accomplished by a TTL input control line with the logic set up such that no signal (floating input) will cause the module to default to the transponder mode.

The second type of receiver/transmitter will have a receiver sensitivity of approximately 65 dbm, and will transmit peak power of approximately 5 watts. This type of receiver/transmitter will be used on the player unit.

It will also pulse on command and indicate when it has received an incoming pulse. However, this module will also interface with other electronics to do the transponder round-trip time measurement when used in the position location system. When it is used for this, the actual time at which a pulse was received will be very critical. Since variations in the time of detection of a pulse are a direct function of the received signal strength, this module will supply a dc signal proportional to the magnitude of the last-received RF pulse. This signal will be latched in the unit until a "clear" input signal has been received from the other electronics in the system.

2-1.2.6 Repeater/Transponder Stations. Because the radio frequencies used will be approximately 1 GHz, all transmissions will be line-of-sight only. If the topography were extremely flat, this would present little difficulty, but the primary TNF S^2 terrain is hilly and forested. The hilly terrain requires that a segmented line-of-sight technique be employed. This necessitates that each player always be within line of sight of at least one repeater which echoes his transmission to other repeaters until it finally reaches the master station. The same is true for transmission to the player. Signal attenuation due to dense foliage decreases the effective range of the communication channel. In situations where this is a problem, the number of repeaters will be increased.

When the communication subsystem is used for position location, the repeaters become transponders during the PL cycle. This mode of operation adds two additional requirements to the installation: (1) the repeater/transponders must be surveyed so that their relative coordinates are accurately known, and (2) they must be "smarter". That is, they must contain the necessary circuitry to enable them to recognize and respond to their own unique ID code. Such a controller could be built uniquely for that purpose or a player pack could be used. While a unique controller would be less costly in terms of hardware, costs of logistics and maintenance might overshadow the difference. These and other trade-offs will be made during the actual design phase of the transponder portion of the instrumentation system.

2-1.2.7 CIU (Communications Interface Unit). The heart of the RF communications subsystem will be the communications interface unit. The CIU will do all handshaking with ECS, generate bit streams based on the message ECS wishes to transmit, decode incoming bit streams, and interface with the other elements of the subsystem.

As was noted before, both the RF communications subsystem and the laser weapons subsystem use similar pulse position encoding schemes. Therefore, to minimize development cost/risk, a CIU is being developed under the laser weapons subsystem. The same CIU will be used for both subsystems. Details of the CIU are given in the subsection which deals with the laser weapons simulator (2-2.3) and will not be given again here.

2-1.3 Player Packs.

The modular design of the player pack allows it to perform in two basic roles in any test scenario. The first is as the familiar manpack or vehicle-pack. The second is as a remote instrumentation controller. As a remote controller it can, for example, gather and store data from a weather station, activate television cameras, etc. The player pack microcomputer (the Executive Control System) is the core of all player pack operations.

2-1.3.1 ECS (Executive Control System). The ECS forms the heart of all player electronics. It will contain the player pack batteries, power conditioners, microcomputer, and connectors for other subsystems. All other modules which are designed to be used with a player pack will operate as peripherals to the ECS computer.

2-1.3.2 ECS Design Philosophy. ECS will be designed as a general-purpose, high-powered microcomputer system with a well-defined buss structure for communication with external peripherals. This will facilitate the development of the other player pack elements which have already been defined and will provide an inherent growth potential as other functions are identified. Further, by treating all other functional elements as computer peripherals, a player pack can be configured to operate in a wide spectrum of modes merely by changing the peripherals which are "plugged in" to its ECS.

In actual operation, the ECS will have to process many kinds of information from various peripherals (e.g., weapon firing, sensor illumination, etc.). Some of these signals are obviously more important than others. Since the signals occur randomly in time, it is possible for several signals to occur simultaneously. To insure that the more important signals are always acquired, ECS will be designed as a prioritized, interrupt-driven system.

When ECS is processing information from the highest priority signal, it is still important that information inputs from other peripherals not be ignored. This will be insured by designing the ECS software as a multi-tasking OS (operating system). In this type of OS, highest priority is given to acquiring data from any signal inputs. All input data are queued and a list of tasks is maintained to indicate which data are to be processed next. If no new data are being received, then the data presently in the queue are processed. This type of operating system (multi-tasking, interrupt-driven) will insure that all data are acquired for processing and that the highest priority data are processed first.

2-1.3.3 ECS Software. As presently envisioned, the ECS will always maintain software drivers for all potential peripheral devices. Any given driver module will be initiated by some external stimulus (such as an interrupt from a peripheral). With this approach, removing peripherals from a player pack will have no impact on ECS operation, it will simply never receive a service request from a "missing" subsystem. Further, part of the bootstrap (restart) software will check to see if certain peripherals are "plugged in."

ECS software is functionally divisible into process control codes and functional computation modules.

2-1.3.3.1 Process Control. The preceding paragraphs describe the features which must be implemented in the process control section of the ECS software. These features have the characteristics of a prioritized, multi-tasking OS (operating system) common on many mini-computers. Figure 6 shows an overview of the ECS software. The OS portion of the software services all interrupts, provides commonly required subroutines, handles all I/O, and controls allocation of CPU (Central Processor Unit) resources to the various computation modules (tasks). The operating system does none of the computations itself; it merely controls the execution of the tasks which perform those functions. The heart of such an operating system is the time-slicing task scheduler. This is where contention for CPU resources is resolved. The scheduler

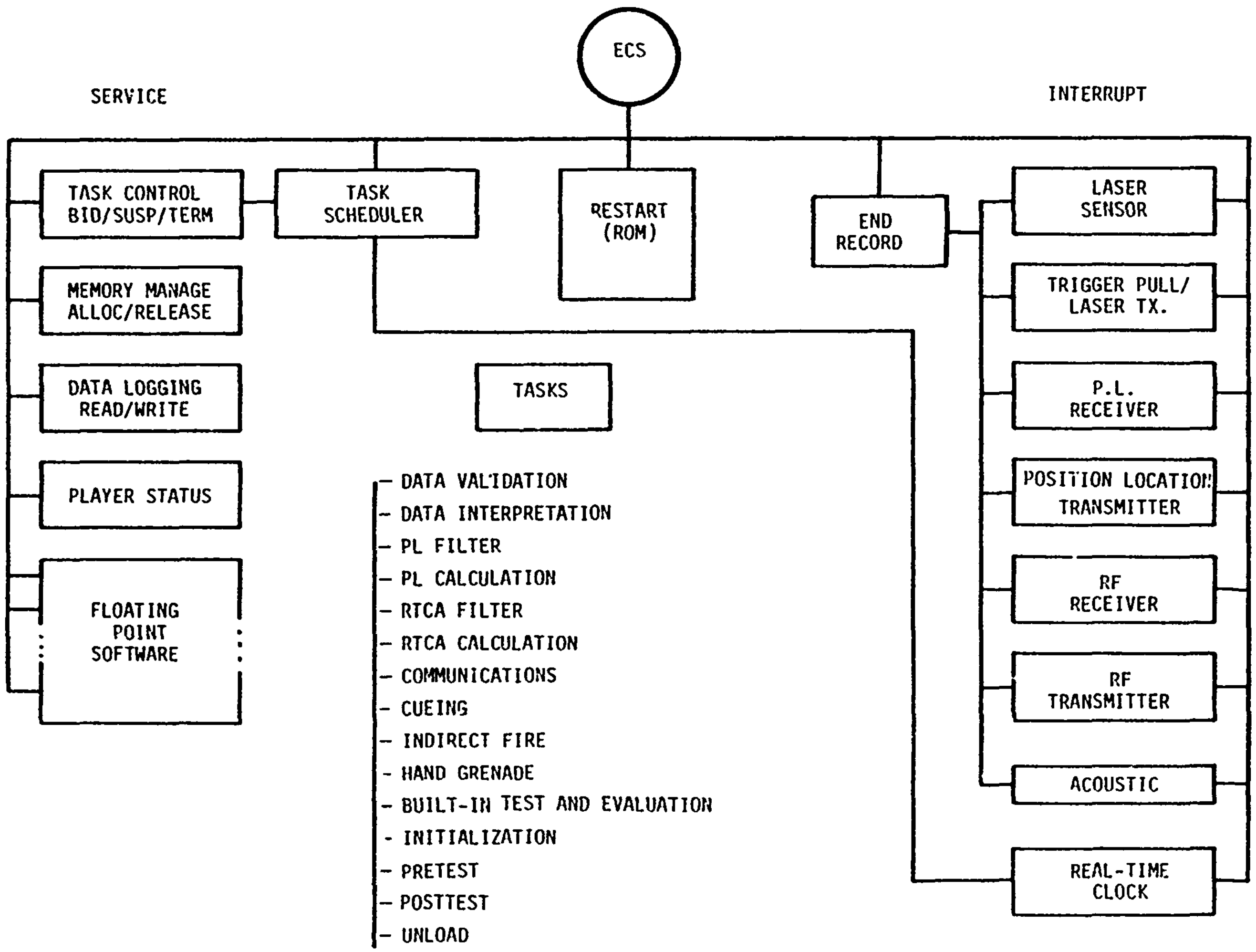


Figure 6. Executive control system overview.

maintains four prioritized lists (queues) of the tasks which have been activated. The scheduler is activated by the real-time clock interrupt. When activated, it terminates the current task and initiates the next task in the highest priority queue. The scheduler initiates a task from one of the lower priority queues every tenth time it is activated (or when high-priority queues are empty). This prevents low-priority tasks from being totally locked out.

2-1.3.3.2 Functional Computation Modules - Tasks. As external conditions change, signals (interrupts) are generated to inform ECS. The OS service routines respond to these signals and activate the appropriate tasks to process the incoming data. Tasks are activated at a priority commensurate with the overall importance of the data channel which initiated the process. The great majority of the tasks involve data validation and interpretation processes. Examples of these tasks follow.

2-1.3.3.2.1 Real-Time Casualty Assessment. RTCA is the means by which objective scoring of weapon engagements is implemented. It is a probabilistic process, calculating the likelihood that the target player is a casualty. There are two basic RTCA tasks, one for line-of-sight weapons (rifles, etc.) and one for indirect fire (artillery, explosives, etc.). These algorithms involve approximately 800 floating point arithmetic calculations, requiring a considerable amount of CPU time.

The RTCA algorithms have a tremendous impact on the total player instrumentation. The calculation process itself, given the required input parameters, is lengthy but straightforward. It is the acquisition of the necessary input parameters to the algorithms which impacts the instrumentation. Because there is no central computer, each player must be instrumented to transmit and receive all the required RTCA parameters.

RTCA algorithms are available from CDEC (Combat Development Experimental Command) and TSEM (the Transportation Safeguard Effectiveness Model). These will have to be modified somewhat for use in TNF S^2 because of the inherent determinism of the distributed system (see Section 2-3, "Constraints and Limitations").

2-1.3.3.2.2 Line-of-Sight Weapon RTCA. The simulators for line-of-sight weapons are low-power boresighted lasers mounted on the actual weapons. RTCA is a two-step process initiated when a player's sensors are illuminated by a laser. The first step is to compute the probability of hit. This probability depends upon (1) the range between players, (2) weapon dispersion, (3) firer posture, (4) firer marksmanship, (5) weapon type, and (6) round type. This information must be transmitted on the laser beam. The second step is to compute the probability of kill given a hit. The parameters required are (1) body area illuminated and (2) vulnerability. This requires that the sensor pattern be available.

These probability calculations must be normalized so that, for a large number of trials, they agree with the hit and kill probabilities derived from actual live-round firing data from AMSAA (Army Material Systems Analysis Agency).

2-1.3.3.2.3 Indirect-Fire RTCA. The algorithms for indirect fire are somewhat less complex, but the simulation method is not (see "Constraints and Limitations" and Section 3, "Weapon Effects Simulation"). The parameters involved are (1) range from the explosion and (2) lethal radius of the round. The RTCA algorithm computes the probability of incapacitation and, once again, must match AMSAA live-round data.

2-1.3.3.2.4 Position Location. Position location algorithms, typically multi-lateration, while more straightforward than RTCA, require floating point arithmetic to prevent loss of precision during the intermediate steps of the process. These algorithms typically require approximately 600 floating point operations - again considerable CPU time is required.

2-1.3.4 ECS Hardware. The hardware configuration of ECS includes the microcomputer, the peripheral buss, the batteries, and the power conditioners.

2-1.3.4.1 Microcomputer. The microcomputer proper occupies one board and includes the microprocessor, priority interrupt controller, address decoder, and the APU (arithmetic processing unit) (Figure 7). An additional board contains the memory and the memory refresh controller. The brassboard and prototypes will utilize all volatile read/write memory so that software modifications indicated by field demonstration results can be quickly incorporated and verified. In this mode, software will be down-loaded from the master station during the operation and maintenance/pretest phases. As the software solidifies, the volatile memory could be replaced with nonvolatile read-only memory.

The APU provides high-speed floating point arithmetic hardware. This relieves the CPU from performing such operations via software. As previously stated, the RTCA and PL algorithms require a great number of such operations. This hardware allows them to execute much faster (10 to 100 times) and greatly reduces the loading factor on the CPU. The reduction in loading is particularly important in planning for future growth.

2-1.3.4.2 Peripheral Buss. The peripheral buss drivers and power conditioners occupy a third circuit board in the microcomputer. The power conditioner section provides regulated ± [illegible], and ± 12 volts from a single 28-volt source. The buss driver section powers the peripheral buss so that each line has the capability to drive 20 TTL loads. The buss itself is connected to 15 parallel connectors, which are used to attach the functional modules. Since the connectors are in parallel, every connector slot is equivalent to every other slot. Consequently, any module may be plugged into any slot. The conceptual brassboard configuration is shown in Figure 8.

2-1.3.4.3 Peripheral Interface. The preliminary peripheral interface standard is:

1. All control, request, interrupt, high-speed, and acknowledge lines are active low (0 volts).

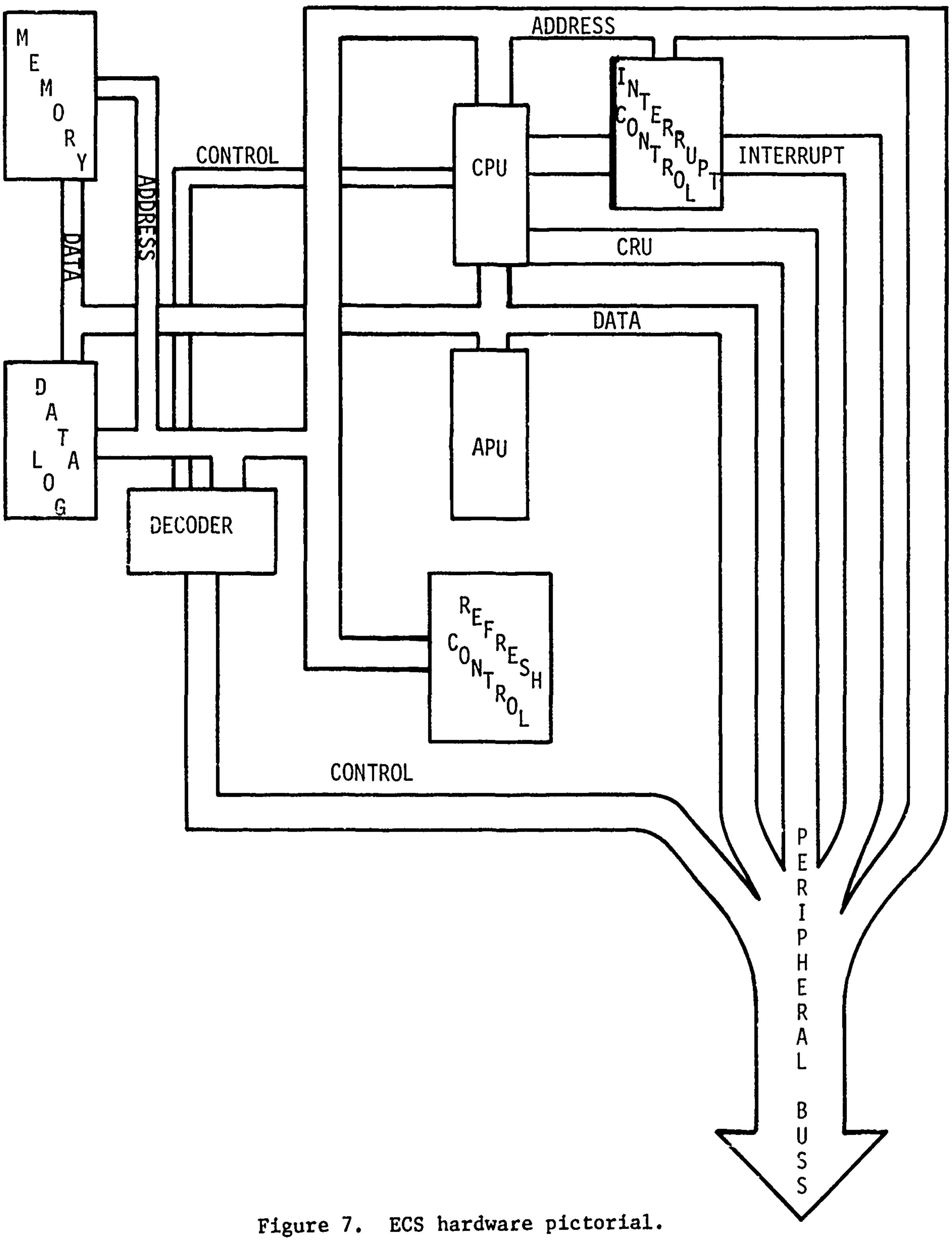


Figure 7. ECS hardware pictorial.

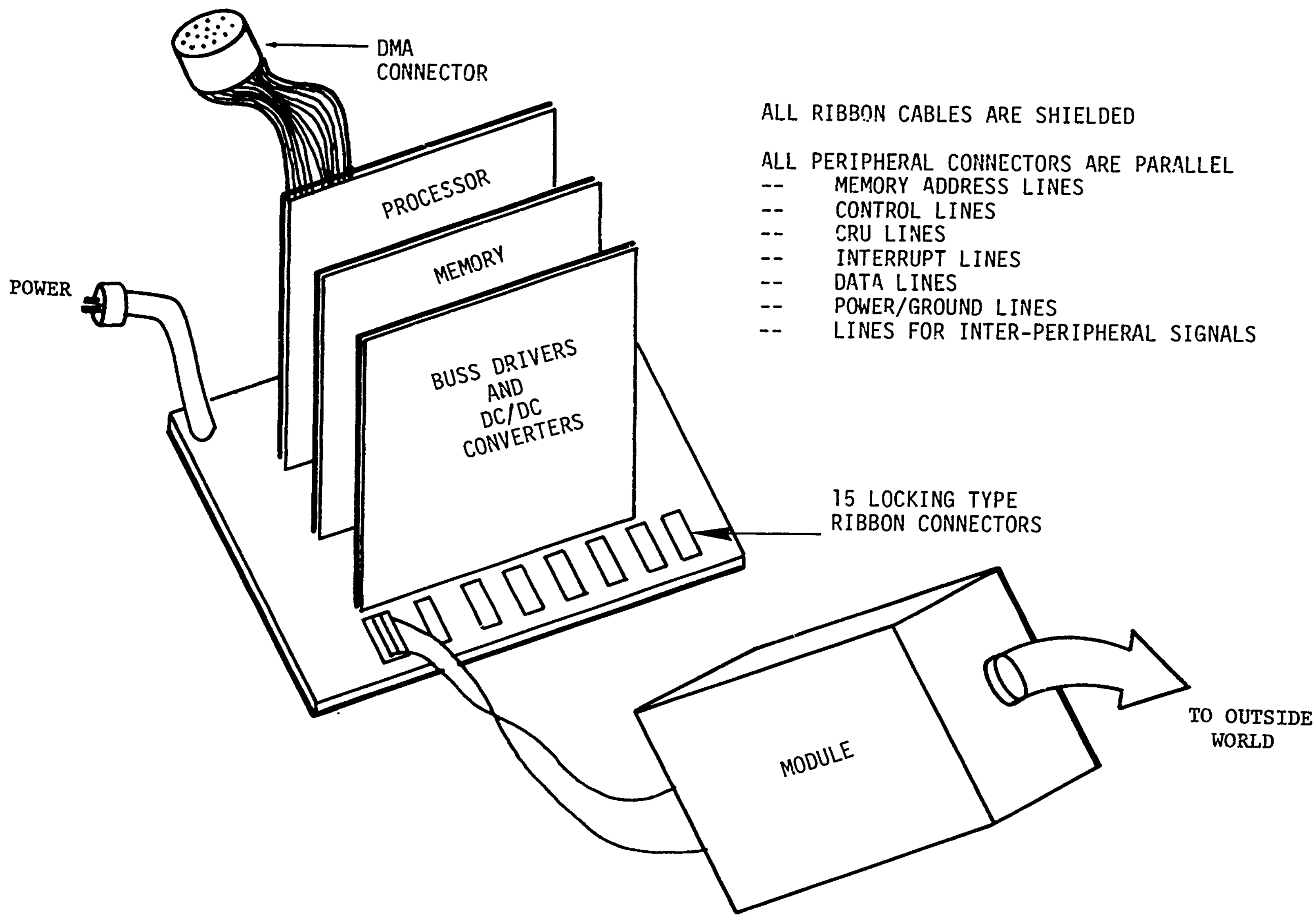


Figure 8. System architecture for brassboard systems.

2. All modules interfacing the peripheral buss shall place one and only one load on any input line used.
3. All outputs to the buss shall be tri-state, high-impedance unless the module is active, and shall drive at least one TTL load when active.
4. Each module shall decode its own unique address non-redundantly and respond if and only if it is referenced.

2-1.3.5 Chassis. The preliminary chassis configuration as shown in Figure 9 is a 25.4-cm-high by 20.3-cm-wide by 10-cm-deep box. A future growth option, as software and hardware solidify, is to hybridize much of the circuitry, conceivably reducing the core electronics to a package not much larger than a hand-held calculator. Restrictions on actually achieving such a package are power requirements (batteries) and the plug-in modules. The hybrid approach is very expensive unless production runs are for quantities greater than 100.

2-1.3.6 Batteries. The envisioned battery compartment occupies 112 cubic inches of the chassis. There are several candidate batteries available which can supply up to 30 watts for 10 hours in such a volume. Battery weight is approximately 6.6 to 11 kilograms. A detailed study of battery trade-off is a part of the FY 1979 task. This study will address throw-away versus rechargeable batteries, power density, availability, safety, weight, size, reliability, and cost.

2-1.3.7 Power Conditioners. A number of supply voltages will be required for proper operation of both ECS and peripheral devices. These voltages will be derived from the battery voltage through the use of dc-dc converters. These voltages will be $\pm$ 5, $\pm$ 12, and 28 volts.

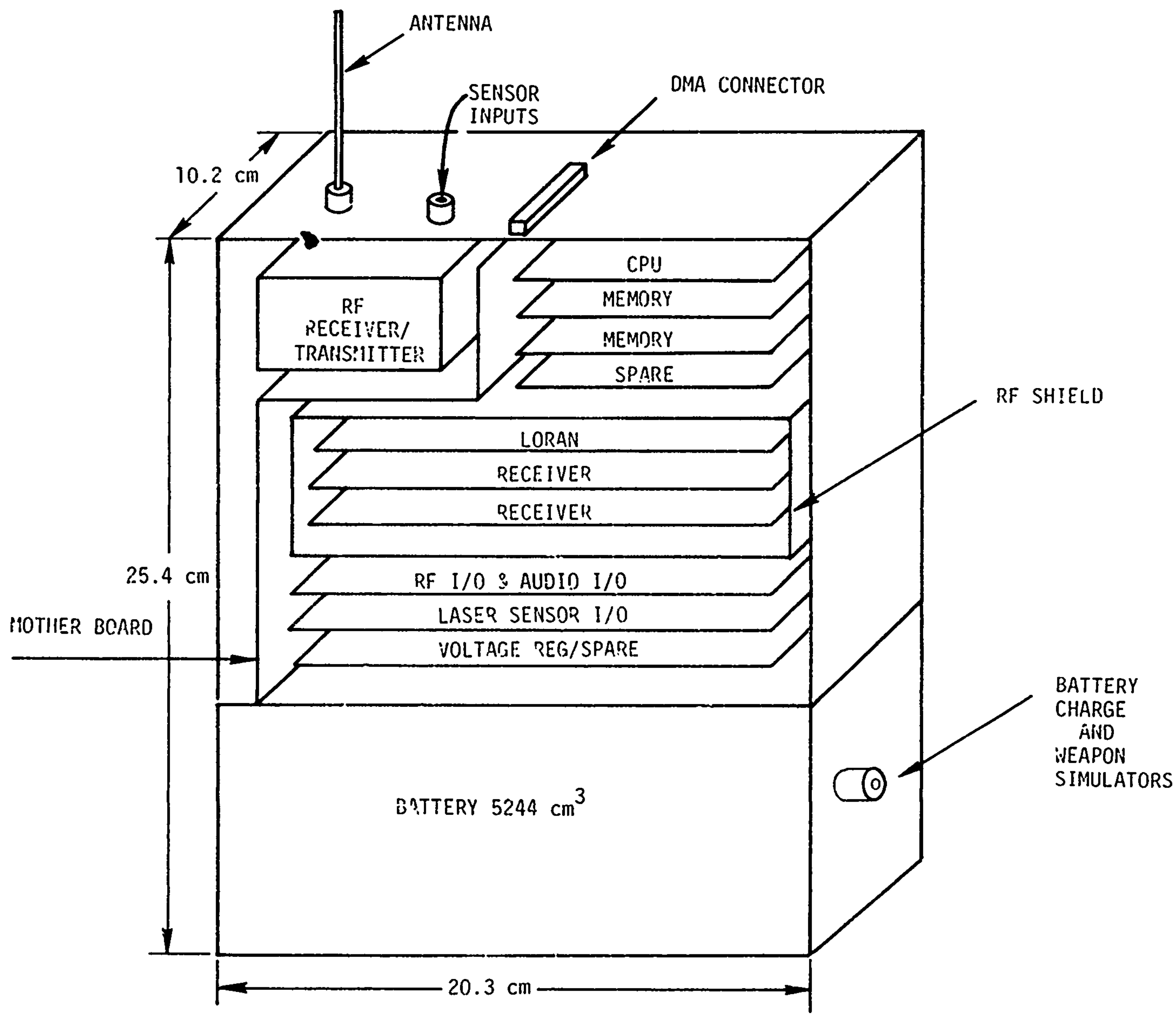


Figure 9. Preliminary chassis configuration.

2-2 DETAILED DESCRIPTION BY FUNCTION.

The subsystem modules provide the functions required of the instrumentation by the TNF S^2 issues. All of the modules have certain common characteristics regardless of their explicit function. These characteristics reflect the philosophies of standardization and modularity central to the overall instrumentation approach.

All of the modules communicate with the CPU over the peripheral buss. Each performs its own address decoding and responds only if it is referenced. The protocol for this process is described in detail in a subsequent paragraph.

All modules carry the necessary switching and control circuitry to allow a command from the CPU to initiate a functional test of the module electronics. The details of such a test naturally vary from module to module, depending on its specific function. In any case, the results are the same - a status bit indicates to the CPU a "go/no-go" signal which informs ECS whether or not the module is operating properly.

The functional hardware modules to be supplied with the initial player packs are:

1. LORAN-C - Medium resolution (15 to 20m) passive position location. Allows an unlimited number of players, but the test must be conducted where there is LORAN coverage.
2. Weapons - Laser weapon simulator modules provide for data transmission over the laser and for laser message decoding through the sensors.
3. Data Logging - Provides mass storage for retention of data on the player for later analytic examination.
4. Radio Communications -Provides for two-way communication and test control.
5. Universal Input/Output - A general-purpose analog/digital I/O module. Controls cueing and "special" devices.

2-2.1 Position Location Subsystem.

2-2.1.1 Introduction. The portion of this study concerned with tracking the location of test participants in the arena of play was the most difficult. The difficulty arose from the competing requirements of accuracy, dynamics, numbers of players, arena topography, and player pack processing capabilities. Assuming the presence of a direct ranging system, it was determined that a position location subsystem had only a posttest mission, not a real-time one. The posttest requirement for the player pack recording of relative position derives from its use in various operations and tactics analyses. A number of analysts were surveyed, and their position location accuracy requirements are listed:

1. Deployment Analysis - 15 to 20 meters.
2. Movement Analysis - 5 to 10 meters.
3. Tactics Analysis - 2 to 5 meters.
4. Decision Criteria Analysis - 2 to 5 meters.
5. Indirect Fire Analysis - 2 to 5 meters.

Environmental requirements for a position location system are day and night operation in hilly and forested terrain containing underbrush. Evaluation of the spectrum of TNF S^2 scenarios revealed the following characteristics:

1. The number of players is typically 30 to 50, with 100 as a maximum.
2. The typical playing area is 2 kilometers square, with the major interactions occurring within a 300 by 300 meter area.
3. The majority of scenarios have elements of close-in interactions between forces, in the region of 5 to 7 meters.

The TNF S^2 test support schedule requires a parallel approach toward the position location problem. The early test capability requirements are for medium-accuracy position location. This can be achieved by the acquisition and modification of existing Loran-C receivers; the discussion of this will follow this paragraph. The instrumentation development for the full capability system requires an integrated position location/communication capability not presently available or under development. Therefore, a position location system development using a line-of-sight technique is required in parallel with an adaptation of Loran-C for early test support.

2-2.1.2 Loran-C Position Location. Since many of the TNF S^2 issues, such as convoy activities, perimeter sensors, and general training exercises, can be accomplished using a 15 to 20 meter accuracy system, Loran-C was chosen for the initial position location system. It is available in two suitable forms and can be provided for an early test capability in the third quarter of FY 1980.

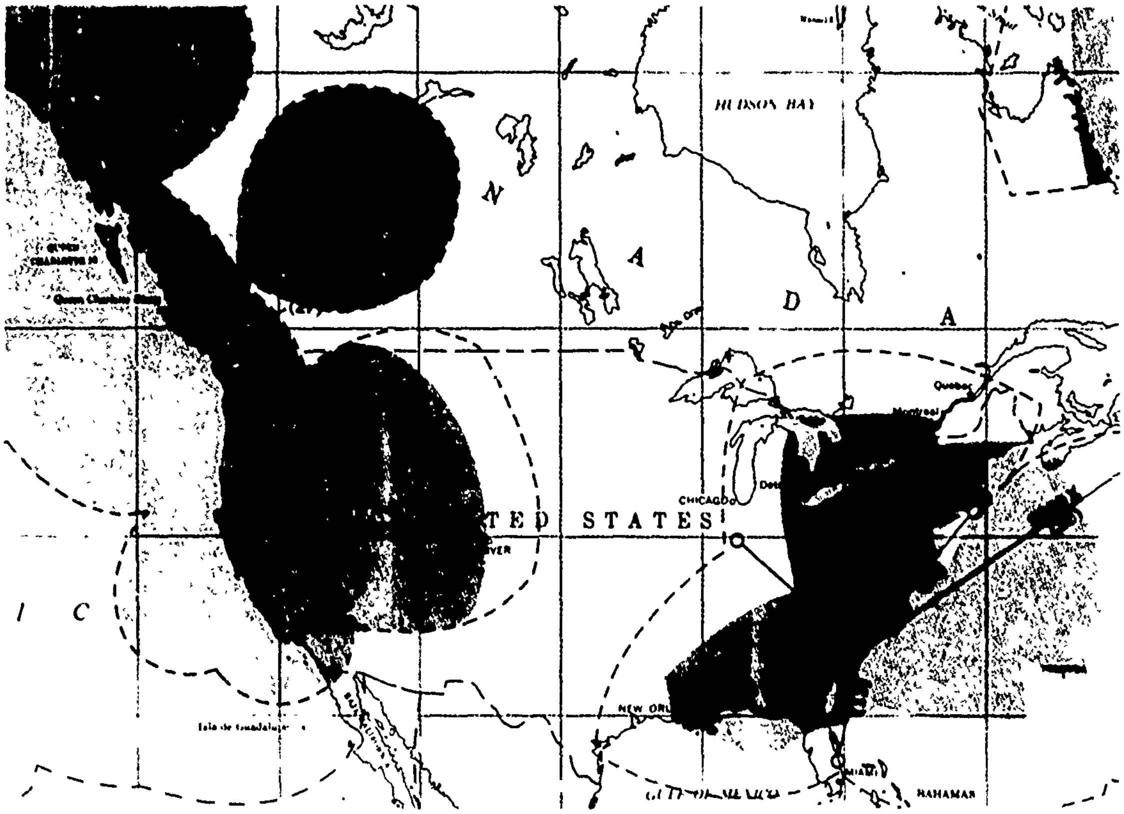
Loran-C is a low-frequency groundwave TDOA (Time Difference of Arrival) multilateration radio navigation system operating in the radio spectrum of 90 to 100 kHz. The Loran-C system consists of transmitting stations in groups called chains. At least three transmitter stations make up a chain, one station being designated as "master" while the others are called "secondaries". Chain coverage area is determined by the transmitted power from each station and the geometry of the stations, including the distance between them and their orientation. The chains currently operational are shown in Figures 10 and 11, "Loran-C Coverage Diagram". The darkest shaded areas are "groundwave fix areas" with a 95 percent fix accuracy (2nd RMS) of 1500 feet with a standard deviation of 0.1 microsecond. The lighter shaded areas are skywave fix areas with a 1.3 signal/noise ratio. The gradient of line of position is less than 2 nautical miles per microsecond, with lines-of-position crossing angles greater than 15 degrees.

Discussions with agencies local to Albuquerque with Loran-C receivers in their aircraft have disclosed that no reliable coverage is possible in this area with the chain configuration shown. For laboratory checkout and calibration, a Loran-C simulator will be a part of the lab support equipment during position location system development.

Within the coverage area, propagation of the Loran-C signal is affected by physical conditions of the earth's surface and atmosphere

NOTE

1. Boundaries shown on this chart are not necessarily authoritative.
2. Geographic names or their spelling do not necessarily reflect recognition of the political status of an area by the United States Government.



GROUNDWAVE – 95% FIX ACCURACY (2dRMS) OF 1500 FEET WITH A STANDARD DEVIATION OF 0.1 MICROSECOND. 1:10 SIGNAL-TO-NOISE RATIO USING NOISE VALUES NOT EXCEEDED MORE THAN 5% OF THE TIME THROUGHOUT THE YEAR.

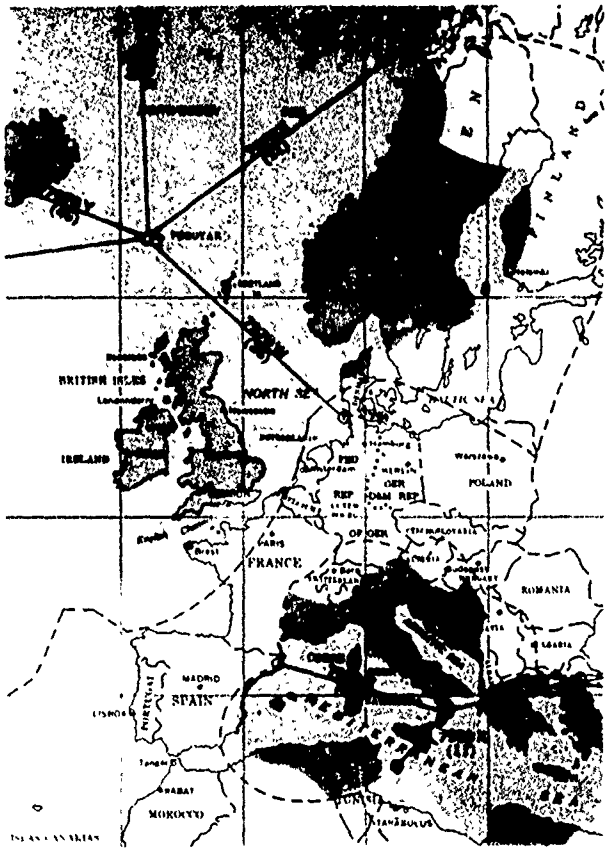
–.–.– SKYWAVE FIX AREA – FOR 1:10 SIGNAL-TO-NOISE RATIO. GRADIENT OF LINE OF POSITION LESS THAN 2 N.M. PER MICROSECOND WITH CROSSING ANGLE GREATER THAN 15°.

ATMOSPHERIC NOISE VALUES USED TO COMPUTE AREA RANGE LIMITS WERE DERIVED FROM INTERNATIONAL RADIO CONSULTATIVE COMMITTEE (CCIR) REPORT 322, 1963.

Figure 10. LORAN-C coverage diagram - United States.

NOTE

1. Boundaries shown on this chart are not necessarily authoritative.
2. Geographic names or their spelling do not necessarily reflect recognition of the political status of an area by the United States Government.



– – – – –   GROUNDWAVE – 95% FIX ACCURACY (2dRMS) OF 1500 FEET WITH A STANDARD DEVIATION OF 0.1 MICROSECOND. 1:10 SIGNAL-TO-NOISE RATIO USING NOISE VALUES NOT EXCEEDED MORE THAN 5% OF THE TIME THROUGHOUT THE YEAR.

–.–.–   SKYWAVE FIX AREA – FOR 1:10 SIGNAL-TO-NOISE RATIO. GRADIENT OF LINE OF POSITION LESS THAN 2 N.M. PER MICROSECOND WITH CROSSING ANGLE GREATER THAN 15°.

ATMOSPHERIC NOISE VALUES USED TO COMPUTE AREA RANGE LIMITS WERE DERIVED FROM INTERNATIONAL RADIO CONSULTATIVE COMMITTEE (CCIR) REPORT 322, 1963.

Figure 11. LORAN-C coverage diagram - Europe.

which must be considered when using the system. Natural and man-made noise is added to the signal and must be taken into account. Receivers determine the applied coverage area by their signal processing techniques and can derive position, velocity, and time information from the transmission. Methods of application provide for conversion of basic signal time of arrival to geographic coordinates, bearing, and distance. All transmitters in the Loran-C system share the same radio frequency spectrum by sending out a burst of short pulses and then remaining silent for a predetermined period. Each chain within the system has a characteristic repetition interval between the pulse bursts which enables receiving equipment to be uniquely synchronized, thereby identifying the chain and stations within the chain being employed.

The effects of the earth's shape, conductivity and permittivity, the atmosphere, and ionosphere, and natural and man-made noise, modify the Loran-C pulse and alter components of the frequency spectrum that must be processed in the receiver.

2-2.1.3 Transponder Position Location.

2-2.1.3.1 Subsystem Functions. This subsystem will be used for precision position location. Each player will determine his position by querying transponders which are strategically placed around the playing area. The transponders will have unique identification codes so that a player can address a specific transponder. By measuring the time it takes for that transponder to respond, the player can determine how far away the transponder is. (The distance between player and transponder will be proportional to the response time minus fixed delays in the electronics.)

This function will be implemented by having the position location system "piggyback" the existing RF communications system. The repeater stations which are used in the RF communications system will also act as position location transponders. Each player's electronics will either receive messages or generate transponder ID codes and measure the round trip signal transit times.

To enhance the position location accuracy, each player will query all position location transponders and will do a least squares fit to all received data. A minimum of three measurements will be required for x, y, and z positions. By doing a least squares fit to all measured data, systematic errors (such as a slow range clock) should be eliminated (for example, four measurements would allow solutions for x, y, z, and clock offset). Thus, position errors will really be a function of differences in signal delays at various transponders, error in transponder placement, etc. If a sufficient number of transponders are used, the overall system accuracy should be between 3 and 5 meters.

2-2.1.3.2 Details of Approach. The position location subsystem will be made compatible with the RF communication subsystem by using a time-slice approach. A certain time interval will be dedicated to RF communication, and a separate time interval dedicated to position location. Control of the system timing will be maintained by having the master station initiate all position location cycles. This procedure is detailed in Figure 12.

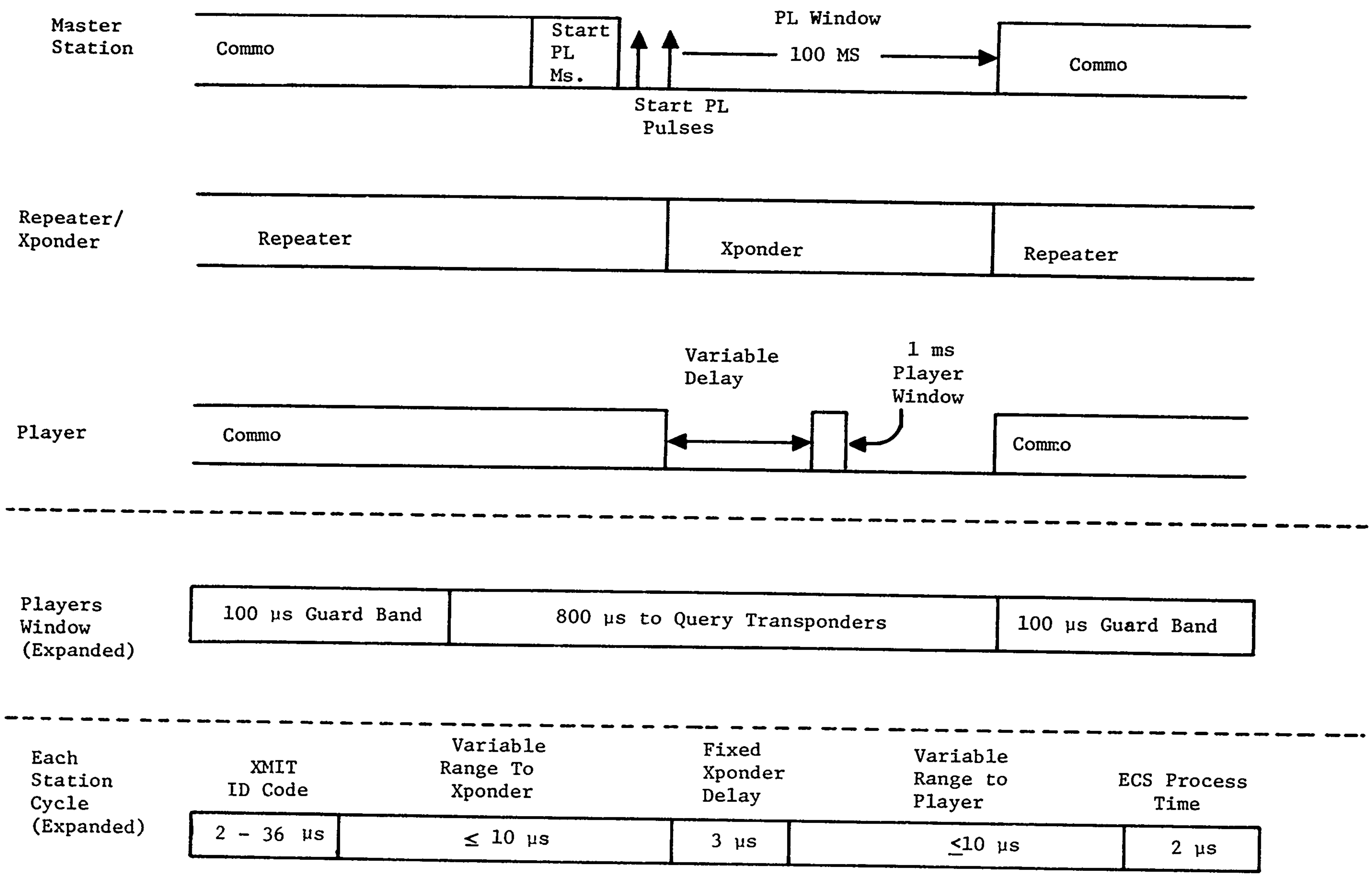


Figure 12. Detailed timing diagram of transponder PL system.

Each PL cycle will be initiated by the master station sending a "begin PL" message. This message will be read by all repeaters and all players so that they will know a position location cycle is being initiated.

After the master station sends the PL message, it will wait several milliseconds to allow the repeaters and players time to interpret the message. It will then send two pulses spaced exactly 20 μs apart, which will start the PL cycle. After it has sent the start pulses, it will wait 100 milliseconds before attempting any further RF communication.

When a repeater receives the "start PL" pulses, it will echo the pulses (to ensure that all players hear the pulses) and immediately switch to the transponder mode. In this mode, it will listen for its ID code. When it recognizes this ID code, it will wait an exact fixed delay (3 μs nominal) and emit a single pulse. The ID code of each transponder will be set by two pulses which are closely spaced in time. The exact spacing will determine the ID code of the transponder being addressed. Thus, an ID code of one might result in a spacing of approximately 21 μs and an ID code of 16 in a spacing of 36 μs.

Each player will have its own time slot in which it can measure the ranges to the PL transponders. The player will listen for the single "PL start" pulse. After it receives this pulse, it will then wait for some variable time (fixed by the player ID number) until its allotted time window occurs. During its window, each player will query all transponders and measure the range to the transponders. Each player's window will be 1 ms wide, with the window time being allotted as shown in Figure 12.

Note that there are 100 μs guard bands on each end of a player's window. This is because all players will not receive the "start PL" gating pulses at the same time. Further, the guard bands allow for some variation in player clocks. The 800 μs which are left should be sufficient for each player to query up to 16 transponders. Details of the timing for a typical transponder query are shown in Figure 12.

2-2.1.3.3 Subsystem Hardware Elements. The transponder position location function will be done by piggybacking the existing RF communications system. That is to say, the existing RF receivers and transmitters will be used so that the only hardware development required for this subsystem will be units which do the digital handshaking with RF communication units and those which do the range determining time measurement (Figure 13). Thus, there will be two kinds of peripherals required which must be developed for this subsystem. These will be a timing control unit which goes on the repeater/transponders, and a timing control unit which will go in the player pack.

2-2.1.3.4 Repeater/Transponder Timing Control Unit. In the RF communication mode, the only function of the repeater was to echo pulses, thus it did not need to know any of the information contained in the messages. In position location mode, however, the repeater/transponder must be able to recognize a "start PL" message. Therefore, the repeater must be "smarter" and will require a communications interface unit and an ECS. Thus, it will be very similar to a player. Further, during the actual PL cycle, the transponder must recognize its ID code (pulse spacing) and immediately transmit a pulse.

The hardware unit which will recognize the transponder's ID code and emit pulses will be a separate peripheral. It will communicate with the transponder's CIU over two dedicated high-speed lines (pulse received and transmit pulse). The ID code of the individual transponders will be entered into this peripheral unit by dip switches or some other alterable electronic means. This ID code will be available to the repeater's ECS.

2-2.1.3.5 Player PL Timing Control Unit. The Player Timing Unit will determine when a player's window has occurred, transmit ID codes for each transponder, measure the time to a returned pulse, and store all measured data in a buffer where they will be available for ECS use.

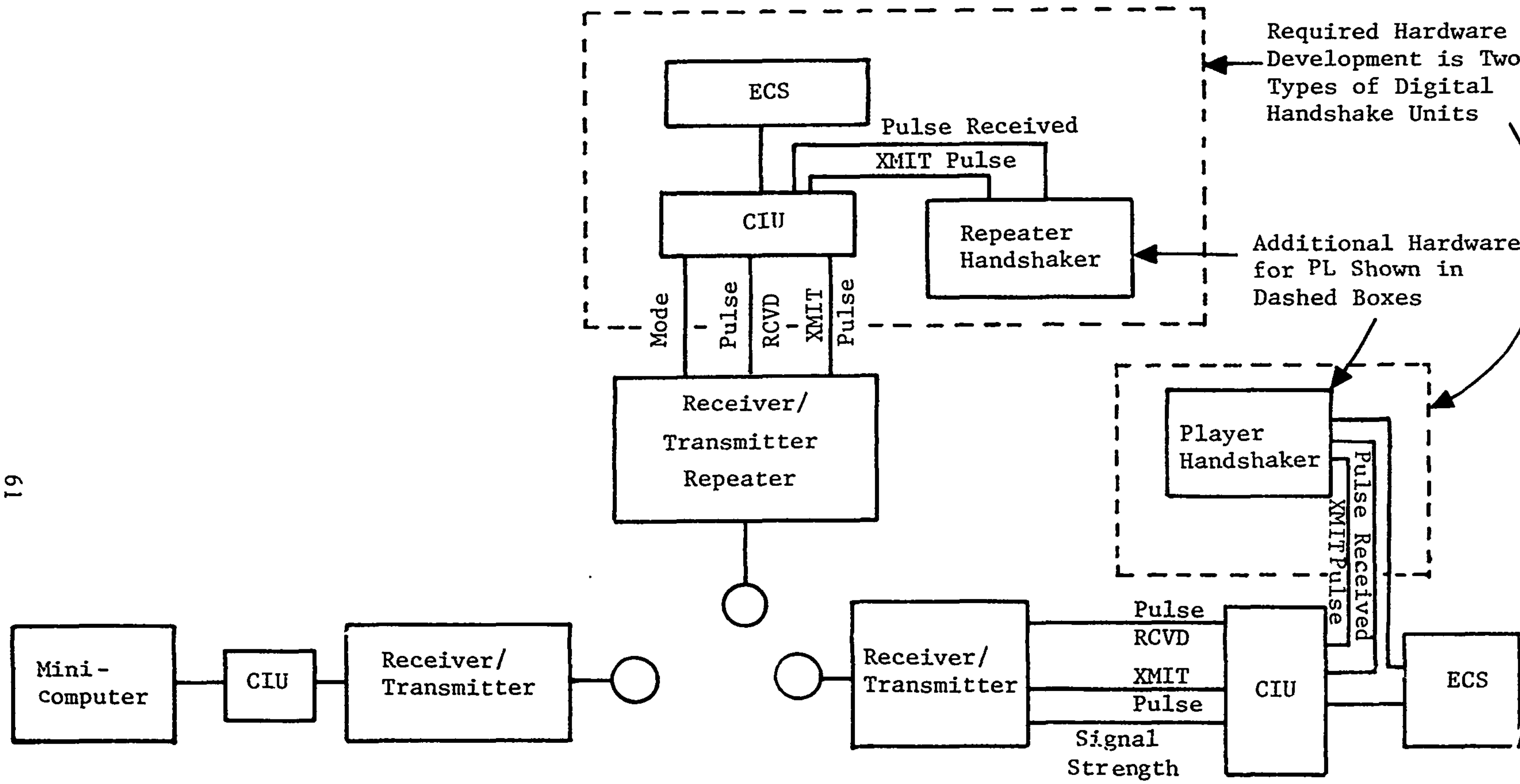


Figure 13. The transponder PL system will be an add-on function to the RF communication system.

A command from ECS (after receiving the "start PL" message) will arm the Player Timing Unit. Then, the first pulse it receives over the dedicated "pulse received" line will begin its cycle.

When it has measured the time delay to the player's window, it will sequentially step through all ID codes for the transponders. For each transponder, it will generate and transmit two pulses spaced .1 to 2 μs apart in time (dependent on the ID code). After the second pulse, it will measure the time until receipt of a "return pulse received" signal and store this time in a buffer. If no pulse is returned within 30 μs, it will store a maximum (over range) number and proceed to the next transponder. For each returned pulse, the Player Timing Unit will also measure the voltage proportional to received RF signal strength and store the level in a separate data buffer.

After it has cycled through all transponder ID numbers, it will notify ECS (interrupt) that data is available. It will also notify ECS when the entire 100 ms PL cycle has ended so that RF communications can be continued.

The location of each player's time slot in the PL cycle is determined by the players's ID code. The player's ID code will be loaded into the Player Timing Unit by ECS.

This unit will be designed with two self-test features. The first feature will enable ECS to read the ID code which is latched into the unit, thus verifying that it is using the right PL time window. The second self-test feature will allow ECS to initiate a self-test cycle, during which the unit will wait a fixed amount of time (approximately 100 ms) and then generate an interrupt to ECS. This will verify that the peripheral's timing clock is working.

2-2.2 Data Logging Subsystem.

The data logging subsystem requirements are determined by considering several aspects: (1) what data must be stored for meaningful analysis, (2) how often each kind of data is expected to be stored, (3) the size of each kind of data record, (4) the anticipated total storage requirement, and (5) how to implement that requirement in hardware.

The data to be stored can be classified as routine tracking records and event-driven records. Routine tracking data provide a position/status versus time/player history. These records are written at regular intervals and allow the analyst to produce a chronological map of player position and status. Event-driven data do not occur at regular intervals, but only as circumstances dictate. These records must contain all the analytically necessary information concerning such events as weapon firing, being fired upon, etc.

To the greatest extent possible. these records should contain the information in immediately usable form to facilitate the quick-look process.

Table 4 shows the information content and record length for the tracking records. Table 5 shows the same information for the event records.

Any given test can be separated into five distinct time regions: (1) pretest checkout, (2) deployment, (3) test data gathering, (4) recall, and (5) data unloading. During each of these times, only records appropriate to the activity in progress are logged. At approximately 5-minute intervals, the Built-in Test (BIT) task logs a record. Table 6 shows the test phases and the types of records logged in each phase. The final figure shows the total data storage requirement to be 95,360 bytes. Because this value exceeds the address space capability of the microcomputer, the data logging subsystem must be implemented as a mass storage device.

Table 4. Tracking records.

Record Type		Data	Number of Bytes
1-Minute	A.	Header	2
		1. What Kind of Record	
		2. Length of Record	
	B.	Time - Hours, Minutes, Seconds	2
	C.	Position	6
	D.	Status	2
	E.	Total Rounds Fired to Date	2
	F.	Total Times Fired At	2
			16
2-Second	A.	Header	2
	B.	Time - Seconds	1
	C.	Position (If Changed)	0 to 6
	D.	Status	1
			4 to 10
Bite Record	A.	Header	2
	B.	Time	2
	C.	System Status (Results)	2 to 4
	D.	Player Status	2
			8 to 10

Table 5. Event records.

Event	Data	Length (Bytes)
Start Test	Header	2
	Title	2
	Test Number	1
	Player ID	2
	Date	1
	System Status	4
	Position	6
		18
Stop Test	Header	2
	Time	2
	Date	2
	Test Number	1
	Player ID	2
	Player Status	2
	System Status	3
	Position	6
		20
Indirect Fire	Header	2
	Time	2
	Status	2
	Position	6
	Round Coordination	6
	Round Type	1
	Pk	4
	Random Number	4
	IAVS, Posture, Results	1
		28

Table 5. Event records (concluded).

Event	Data	Length (Bytes)
Weapon Firing	Header	2
	Time	2
	Status	2
	Position	6
	Firing Mode, Round Type, Marksman Level	1
	Weapon Type	1
		14
Fired Upon	Header	2
	Time	2
	Status and Posture	2
	Position	6
	Attacker Position	6
	Attacker ID	1
	Weapon Type	1
	Firing Mode, Round Type, Marksman Level	1
	Range	4
	Direct Range (RAW)	2
	Sensor Pattern	3
	Pk	4
	Random Number	4
	Results, New Status	2
	TBD	4
		44

Table 6. Typical test sequence.

Test Phase	Time (Hours)	Record Type	Length	Number	Total (Bytes)
Pretrial C/O	3.5	1-Minute	16	20	320
		Event	30	10	300
Deployment	0.5	1-Minute	16	30	480
Test	4.0	1-Minute	16	240	3,840
		2-Second	10	7,200	72,000
		Event	30	500	15,000
Recall	0.5	1-Minute	16	30	480
Data Unload	1.5	1-Minute	16	90	1,440
		Event	30	10	300
Self-Test		Self-Test	10	120	1,200
Total	10.0			8,250	95,360

2-2.2.1 Data Logging Hardware. Because the data logging subsystem must be structured as a mass storage device, it can be discussed as two functionally distinct blocks: (1) the storage medium and (2) the storage controller.

2-2.2.1.1 Data Storage Medium. Functionally, the medium stores the data presented to it under command of the controller. To cover the wide range of conditions envisioned, two distinct storage media are proposed. The first is a miniature cassette. This is a very low-risk option, highly suitable for non-human-carried applications. The second medium, tailored for man-carried applications, is a dynamic random access memory array. The memory array has the advantage of very small size and weight, but is considerably more expensive than the cassette.

As alternate technologies mature (i.e., magnetic bubbles, etc.), they could be easily implemented as conditions dictate.

2-2.2.1.2 Data Storage Controller. The controller consists of three interacting sections: a CMOS buffer memory for low-power data accumulation, a DMAC (direct memory access controller) to effect the transfer from the CMOS buffer to the storage medium, and an interface to the storage medium. Thus, the interface to ECS (the CMOS buffer) is independent of the choice of the actual storage medium used. Consequently, the same controller will be used for either the cassette tape or the dynamic memory storage medium. Operation proceeds as follows:

To store data -

1. The CPU writes to the buffer until it is full.
2. The CPU powers up the DMAC and instructs it to transfer the contents of the buffer to the storage medium.
3. The DMAC issues an interrupt to the CPU when it is finished.
4. The CPU removes power from the DMAC.

To retrieve data -

1. The CPU powers up the DMAC and instructs it to fill the buffer from the storage medium.

2. The CPU transfers data from the buffer to the master station by whatever means are employed (RF, wire, etc.).

3. The CPU removes power from the DMAC.

2-2.3 Laser Weapon Simulator Subsystem.

2-2.3.1 Subsystem Functions. The primary function of the laser weapon simulator subsystem will be to provide pairing between line-of-sight weapons, such as rifles, and the targeted player. These weapon simulators will be designed so that, in conjunction with other subsystems, they can also be used to measure the range between a firing weapon and target. The details of how these functions will be performed are given below:

2-2.3.1.1 Pairing. Weapon/target pairing will be done by having a laser transmitter mounted and boresighted on the weapon barrel. When the weapon is fired, the laser will transmit a narrow beam of light. Sensors mounted on the target will detect the laser light and signal the target player's ECS that he has been shot. Figure 14 illustrates the player-carried instrumentation.

In this instrumentation system, the characteristics of laser beam spread are more critical than in systems which are tied to a central computer. In a centralized system, the laser beam can be allowed to spread over a relatively large angle and any unrealistic effects, such as illuminating and "killing" many targets with one shot, can be easily prevented with software. This system, however, will be highly decentralized, with each target being totally unaware of the illumination of an adjacent target. This means that the laser beam will have to have a fairly small dispersion to prevent these unrealistic effects. An initial specification placed on this divergence is that the probability of hitting two adjacent man-sized targets will be less than .1 at 100 meters (Figure 15).

Using a beam with this small a divergence places other constraints on the system since, at close distances, it would be possible to shoot a target and have the beam miss all sensors. Consequently, the

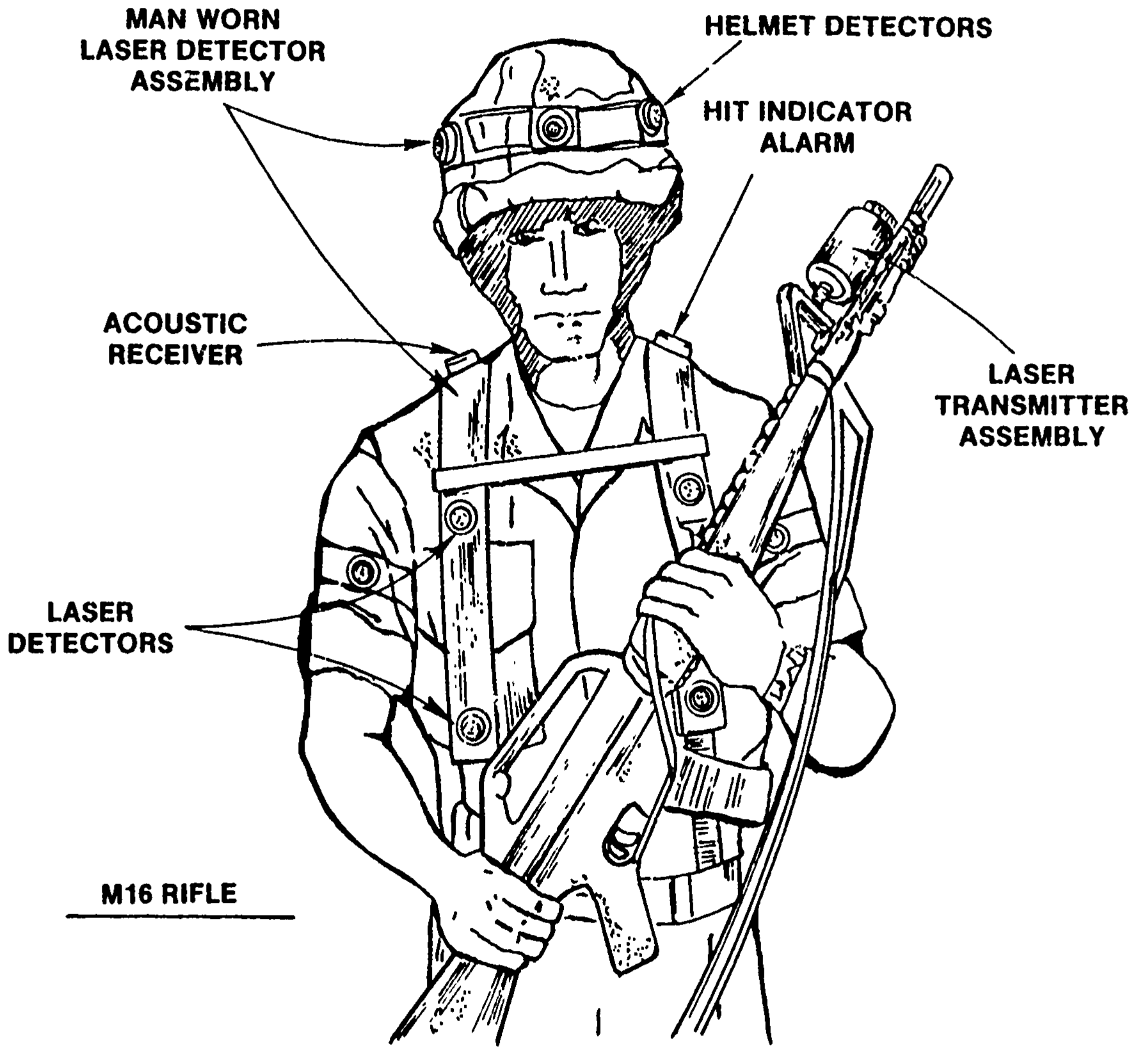


Figure 14. Player-carried instrumentation.

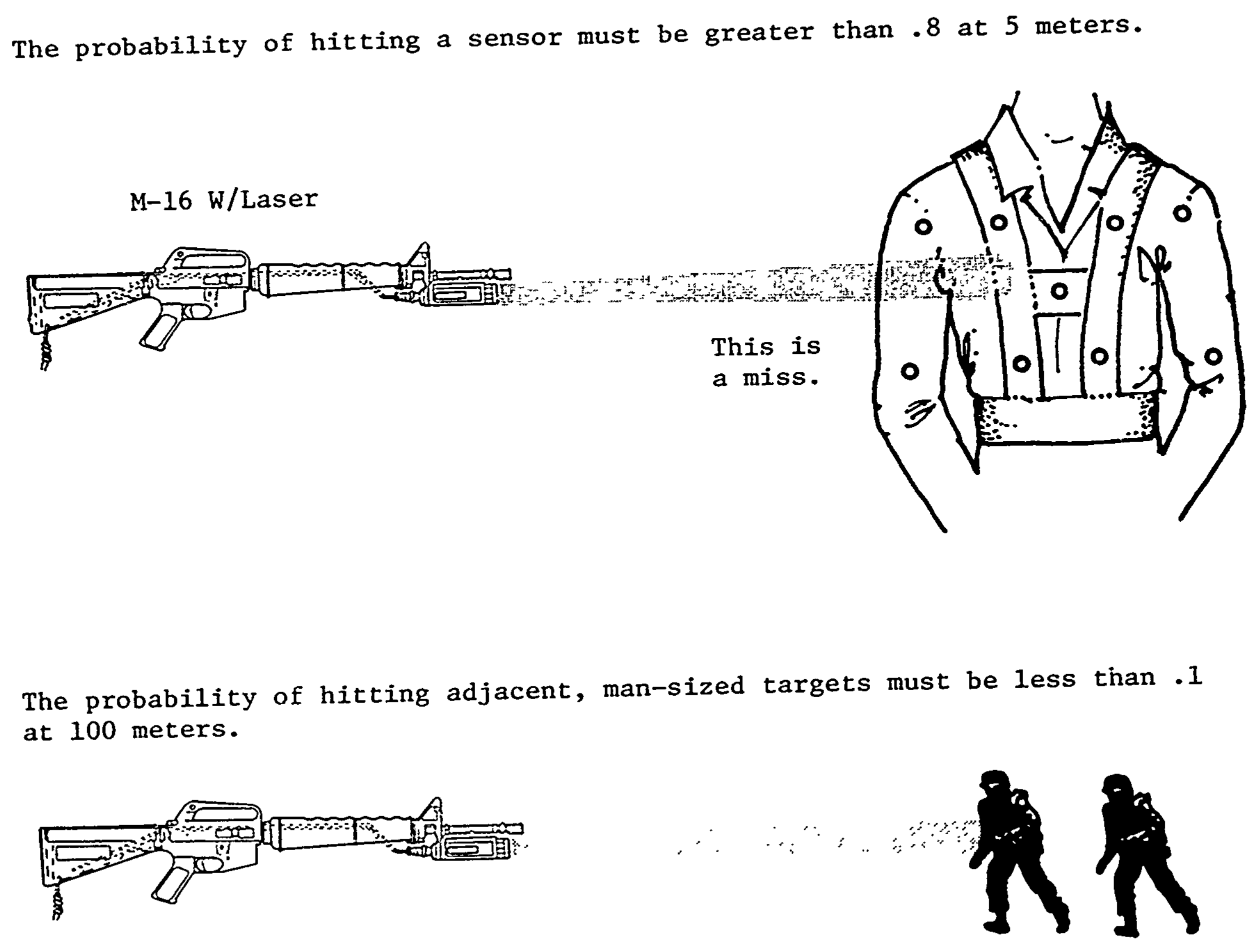


Figure 15. Laser pairing specifications.

sensors will be spaced on the players so that a shot from as close as 5 meters must have a probability of greater than .8 of hitting a sensor.

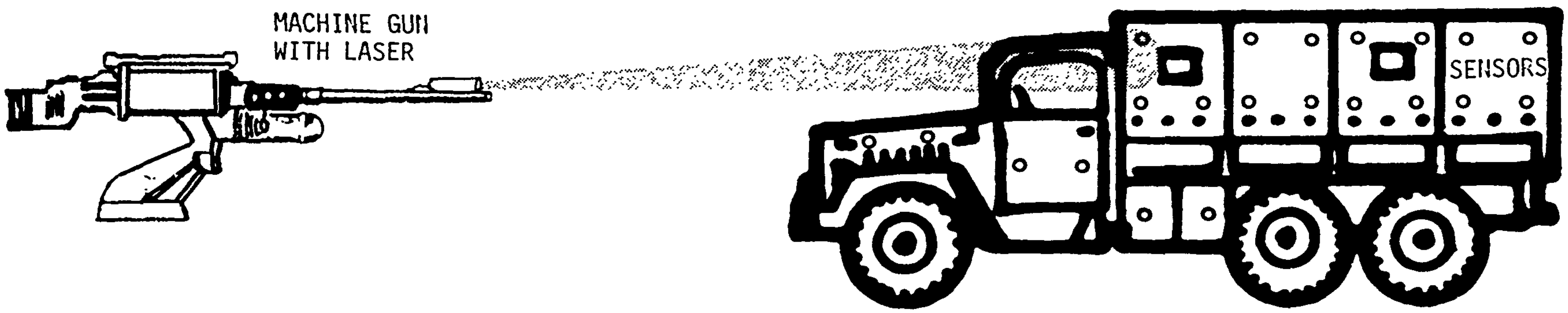
This combination of laser pairing specifications creates some problems with instrumenting large objects such as trucks (Figure 16). Essentially what this means is that a large number of sensors will have to be used and that the sensors will probably have to be clustered around the vulnerable points.

Pairing of a weapon and target is important for RTCA (real-time casualty assessment). However, before a valid RTCA decision can be made, other information must be available. Among other things, this information includes location of the hit on the target and any shielding of the target.

The location of hit on the target will be measured by having each sensor individually instrumented. Shielding information can be derived when the slant range is fairly large (so that several sensors would be simultaneously illuminated) by detecting the hit pattern on the sensors. At close ranges (< 10 m), where only one sensor would be illuminated, shielding could not be inferred, but that is an operatonal limitation which must be tolerated.

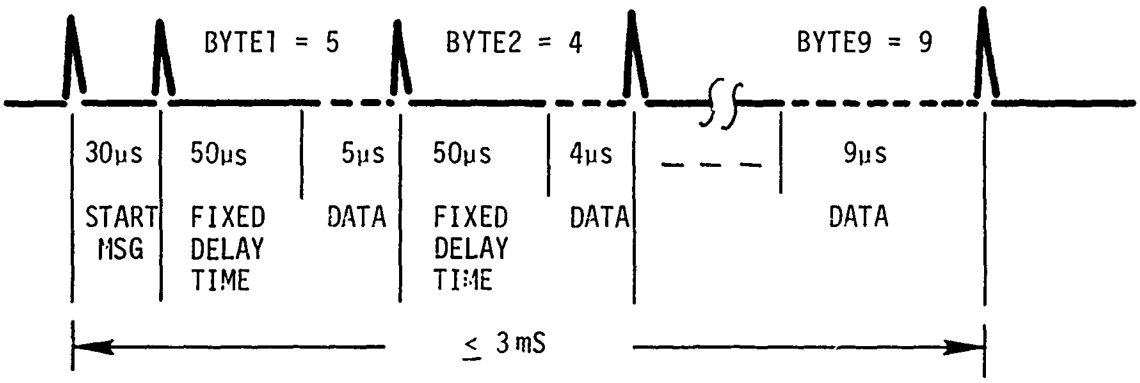
The other information required for RTCA concerns characteristics of the firing player. This information will be transmitted over the laser beam each time a round is fired, so that the target player can do its own RTCA. A preliminary list of the information to be transmitted is shown in Table 7, along with the number of bits each message element requires.

Data will be encoded on the laser beam using a pulse positioning scheme. In this scheme, each message will have two pulses spaced exactly 30 μs apart to indicate the start of a message. A series of 9 pulses will then be sent, with each pulse containing 8 "bits" of information. The 8 bits of information will be carried on each pulse by varying its delay from the previous pulse (Figure 17). Based on the recovery time of the laser circuitry and the clock requirements to measure delay, the pulses will be a minimum of 50 μs apart and a maximum of 303 μs apart.

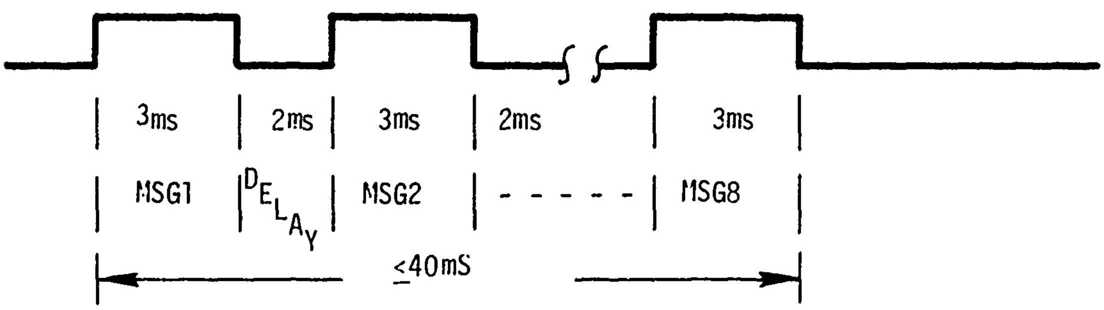


VEHICLES REQUIRE A LARGE NUMBER OF SENSORS

Figure 16. Sensor problems with vehicles.



EACH LASER MESSAGE WILL CONTAIN 2 START PULSES AND 9 DATA PULSES OF 8 BITS EACH.



EACH LASER MESSAGE WILL BE REPEATED 8 TIMES

Figure 17. Data encoding for laser messages.

Therefore, a complete 72-bit message could take up to 3 milliseconds to send.

Table 7. Laser Transmitted Data

Information	Number of Bits
Firer ID	9
Weapon ID	9
Round Type	2
Firer Posture	2
Firer Position	36
Marksmanship Level	3
Firing Mode	1
Spare	10
	72

The pulse positioning scheme was chosen since it allows the laser pulser to emit very high peak power signals with low total energy drain. It also allows a low duty cycle on the lasers to avoid heating effects, etc., and it makes data transmission relatively insensitive to range. The specification on message reliability will be a probability of .75 to transmit an entire valid message with a weapon-target separation of 1500 meters.

2-2.3.1.2 Distance Measurement to Explosive Simulators. Incorporation of hand grenades and similar weapons into a war-gaming test system has always been a problem. If a centralized computer is used, it must know the location of the explosion (which implies a sophisticated simulator), the location of players in the area, and the location of any shielding. The TNF S^2 system will get around this problem by using explosive simulators which emit light (flash) and noise (bang) in a manner which allows them to be uniquely distinguished from background noise. Then, by using the propagation velocity of light and sound, and the time difference of arrival of the two signals at the player, the distance to the simulator can be calculated separately by each affected player. This is discussed in more detail in the Section 3, "Weapon Effects Simulation." The relevant point here is that the simulator will emit a light pulse which is much wider than either a laser pulse or a weapon's muzzle flash. The player's laser weapon simulator subsystem will detect this light, determine if it is a wide pulse, and notify the player's ECS. Detection of the simulator sound and the time measurement will be done by the direct ranging subsystem.

It should be noted that due to the slow propagation velocity of sound in air (≈ 300 m/s), a time measurement uncertainty of as much as 10 ms would result in a range error of < 3 meters. This implies that the interaction between the laser weapon subsystem and the audio detection subsystem can easily be handled through ECS using interrupt-driven software.

2-2.3.1.3 Direct Distance Measurement Between Weapons and Targets. One of the major factors which influences the RTCA calculation is the separation (slant range) between weapon and target. For the initial system, this range will be calculated from the difference between the weapon's and target's position (Delta PL). However, this type of ranging cannot be used in a scenario where either player is shielded from receiving PL signals (possibly inside an aircraft hangar). Therefore, one growth option envisioned for this system is the ability for the target player to directly measure the range to the attacking weapon.

There are two possible approaches to this function which are addressed in detail under direct ranging in Section 2-2.6 of this report. The option of interest here is the RF-Laser transponder approach. With this approach, the target desiring range would emit a single pulse of RF (on a different frequency than RF communications). A directional receiving antenna mounted on the weapon would sense the pulse and immediately cause transmission of a single laser pulse. The round trip time from the emitted RF pulse to the received laser signal would yield the slant range.

Achieving this capability influences the design of the laser simulator subsystem. First, to insure a measuring accuracy of 5 meters, the total time measurement uncertainty must be less than 16 ns. This means that the time between reception of the RF pulse and transmission of the laser pulse might be tightly controlled. It also means that the detection uncertainty of the laser pulse and propagation delays of the detected signals back to ECS must also be very tightly controlled.

A further consideration is that one player could possibly initiate a pulse from more than one weapon. This possibility will be minimized by having the weapon-mounted antenna be as directional as possible (given the constraints dictated by physical size). A second limiting factor will be that the laser will only be allowed to transpond for a short period of time (beginning 5 ms and ending 10 ms) after each message is complete.

2-2.3.2 Subsystem Hardware Elements. There will be three basic elements to the Laser Weapon Simulator Subsystem: weapon-mounted circuitry, detector harness, and ECS interface (communication interface unit). Details of these elements are given below.

2-2.3.2.1 Weapon Mounted Circuitry. The weapon-mounted circuitry will detect that a weapon has fired a round and will also emit laser pulses on command.

The firing of a round will be detected by an optical sensor which senses muzzle flash. When a flash is detected, the weapon will notify the interface circuitry and wait for commands. A message will then be generated and sent to the weapon as a series of pulses. Each time a data pulse command is received, the weapon-mounted circuitry will emit a single laser pulse and enable the special (direct ranging) laser triggering input for the time specified above.

The time delays between receipt of a normal pulse command and a laser emission can be fairly long (delays from unit to unit may vary by up to 100 ns), but the time delay from the special pulse input and a laser pulse must be very tightly controlled (5 ns variation worst case).

One special design difficulty with the weapon-mounted circuitry is that there will be a number of weapon types available, and any given player may use one of several in an unstructured time sequence (e.g., rifle and handgun). Since the attacking player must transmit weapon type as part of the laser message (to allow target RTCA), this means that the attacking player's ECS must know which type of weapon was fired. This problem is further complicated by the fact that it would impact realism to have a separate umbilical for each weapon a player is carrying, especially if the number becomes larger than two or three.

This difficulty will be solved with a two-fold approach. First, the data link between the weapon and interface circuitry will be over a proximity-coupled RF link so that there will be no permanent player-weapon electrical connection and, second, the weapon-mounted circuitry will transmit an ID code when it detects a fired round so that ECS will know which weapon type was fired.

The coupling between the weapon and player will be done using a coupled "transmission line" as shown in Figure 18. In this approach, both the player and weapon will have a co-axial cable which makes contact to one side of a coupling network. When the two networks are brought into close proximity (< 1 inch) signals will be transmitted between the two system elements.

To insure a good coupling, the networks will have to be mounted where they will always be physically close when a player is firing a weapon. This will be done by having the networks mounted to the weapon stock and to the palm of a glove which the player will wear.

If initial tests indicate that reliable coupling cannot be achieved using this approach, an alternative will be to use conductive tape on the weapon trigger and stock.

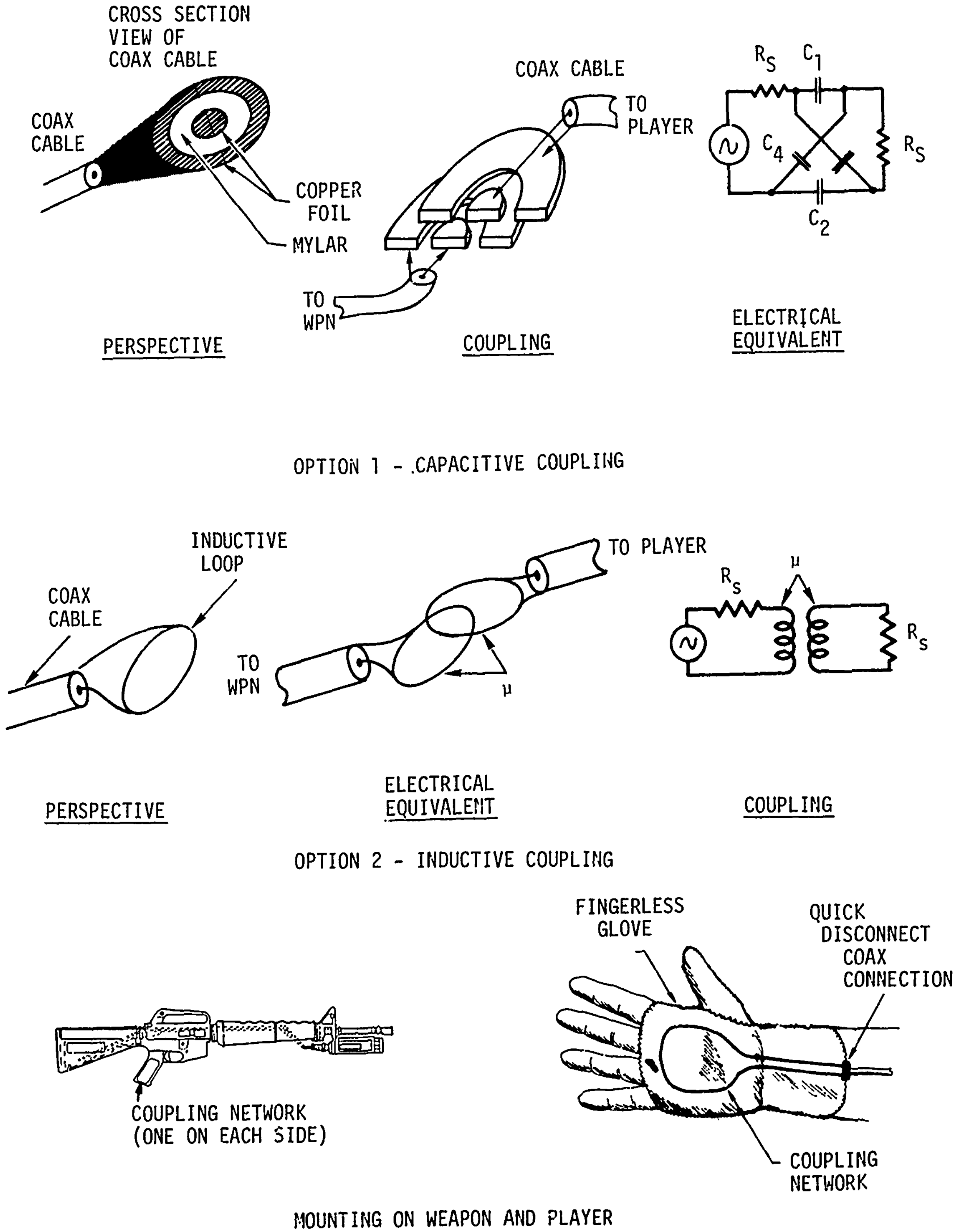


Figure 18. Proximity coupling networks between weapon and player.

The weapon will transmit its type by emitting two pulses, the separation between pulses being proportional to its ID number. To simplify data decoding, the bit increments will be 1 μs, as in laser data transmission. Since there will be the possibility of 16 weapon types, the separation between pulses will be between 1 and 16 μs (weapon types 0 through 15) for a properly operating weapon.

The weapon type will be selected by the use of "DIP" switches (4, single-pole, double-throw) mounted in the weapon circuitry. The circuitry will be designed so that a closure to ground will be necessary to program either a 1 or a 0. If both or neither conditions exist on any bit, the system will default to an invalid weapon type which, when the next round is fired, wil notify ECS that the weapon is malfunctioning.

This feature will be incorporated into the system by having the weapon circuitry transmit 6 bits (4 data plus 2 status). Thus, a malfunctioning weapon could have an apparent ID number as large as 64 (64 μs pulse-to-pulse spacing). Note that this scheme allows ECS to know which of its several weapons is suspect.

The second status bit will be used to monitor current through the laser diode. Every time a data pulse command is received, the circuitry will determine if a current pulse goes through the laser diode within the following 1 μs. If none has been detected within that time, the error bit will be set.

There will eventually be a large number of weapon types used in this system. The only difference between weapons will be the way in which the circuitry physically mounts to a weapon and the way muzzle flash detection is done. The schedule for weapon incorporation into the test system is given separately in Section 4, but for the first year, three weapon types will have mounting schemes developed. These types are the M-16, light machine gun, and 45-caliber handgun.

2-2.3.2.2 Detector Harness. The detector harness will detect when a light pulse occurs and will transmit a signal to ECS for the entire duration of the detected light pulse. Since hit location and pattern are desired for RTCA, each sensor (or group of sensors) will have a separate data line to the peripheral interface electronics.

Based on separate studies, it appears that 16 sensors will be sufficient to instrument a man-sized target and insure accurate RTCA.

As was previously mentioned, the size of a vehicle dictates that its detector harness contain considerably more sensors than required for a human. However, for compatibility with ECS, the number of sensor input signals must be limited to 16 or fewer. Consequently, the discrete sensors will be grouped into sets, with each set providing a single signal. Thus, there can be up to 16 sets of sensors, each set consisting of the number of discrete sensors required to adequately cover the area of the vehicle in question. Then, when any sensors of a given group are illuminated, the data line assigned to that entire group will be activated.

One design trade-off associated with the detector harness is the speed of the detectors. For normal communication they need only be fast enough to insure data transmission. If the harness is used for direct ranging, however, the detection uncertainty must be very small (high-speed). Since there is a trade-off between speed and power (even stand-by power), it is unclear what the effect on system power consumption would be if the detectors are designed to always be high-speed. Part of the first year's effort will be to determine whether separate high-speed harnesses are required for direct ranging, or if some type of high-speed enabling signal could be used to limit detector high-power consumption to times when it is necessary.

As presently envisioned, the only self-test feature which will be incorporated into the detector harness will be to insure that it is drawing power. If not, the interface unit will set an error flag for ECS.

2-2.3.2.3 Communications Interface Unit. The heart of the laser weapon simulator subsystem will be the CIU (communications interface unit). The CIU will do all handshaking with ECS, generate bit streams based on the message ECS wishes to transmit, decode incoming bit streams, and interface with the other elements of the subsystem.

It should be noted that both the laser subsystem and the RF communication subsystem use pulse position encoding. For various reasons the optimum timing in both systems is the same. With this in mind, and to minimize development cost/risk, the CIU will be designed to service either system. The type of subsystem for which it is being used will be strap-selectable. The CIU will be described in detail here, with a special note about any unique features required by the RF subsystem.

The CIU can best be described by addressing its interface with other subsystem elements, the functions it will perform, and its interface with ECS.

2-2.3.2.3.1 CIU Interface to Other Elements. The CIU will basically share five signals with other subsystem elements. These are:

1. Round fired - This will be two pulses received by CIU over the bi-directional link with the weapon-mounted circuitry.
2. Pulse detected - This will be a signal from either the laser detector harness or the RF receiver. When the CIU is selected for use with the laser subsystem, there will be 16 input lines. When used with the RF subsystem, only one input will be used.
3. Transmit a pulse - This will be a command to either the RF transmitter (over a dedicated line) or the weapon-mounted circuitry (bi-directional line) commanding a single pulse to be transmitted.
4. Set the RF module mode - This will be a command line to the RF module to determine if it should act as a repeater or a receiver/ transmitter.
5. RF signal strength - The RF module will output a signal proportional to the signal strength of the last received pulse.

2-2.3.2.3.2 CIU Functions. The CIU will perform the following functions:

1. Notify ECS when a round has been fired (laser system only), and the weapon type which was fired.
2. Transmit a pulse data stream - When ECS has loaded the interface unit's data buffer, it will command the interface unit to transmit the message. The interface unit will then use the

stored data to generate the appropriate pulse stream and will pulse the external circuitry to send the message. It will send the complete message eight times for the laser system and one time for the RF system, and will then notify ECS that it has finished.

3. Decode an incoming message - When the sensor circuitry transmits received pulses to the interface unit, it will decode the message and place it into a storage buffer. It will determine whether a complete message has been received and, if so, will notify ECS that it has a message to be read. Once ECS has been notified, the data buffer will remain unchanged until ECS acknowledges that it has read the message.

4. Determine the sensor "hit pattern" - The interface unit will be able to determine which sensors were illuminated for a given message. If an incomplete message is received, then the pattern latch circuitry will be cleared. If a good message is received, then the pattern will be frozen until ECS acknowledges that it has read the message (and the pattern). This will be used in the laser subsystem only.

4. Discriminate a wide light pulse - Anytime a received pulse is longer than 10 ms, the interface unit will notify ECS that it has detected a wide pulse. This function will be disabled in the RF mode.

6. Buffer special signals - There will be three special signals which will connect directly to other peripherals over dedicated lines. These are: emit a pulse, pulse received, and RF signal strength. RF signal strength will be routed directly through the CIU. The other two signals will be "and'ed" with control bits and transmitted directly through the system with minimum delay.

7. Self-test - As has already been mentioned, there will be two types of continuing self-tests built into the weapon-mounted electronics and one type of continuous self-test for the detector

harness. In addition to these, the CIU will have its own self-test to monitor its message encoding/decoding circuitry. Essentially, this test will be to load the CIU transmit buffer and initiate a self-test cycle. The circuitry will then encode a message and attempt to send it. Instead of actually being transmitted, however, the signal will be wrapped around into the decoding circuitry and then into the output buffer. Therefore, ECS can use any dummy message for self-test and can verify that the same message was "received."

2-2.3.2.3.3 Interface to ECS. The CIU will perform all communication with ECS and other peripherals through an ECS peripheral connector (see "System Architecture").

The memory locations and interrupt line assignment for the interface unit will be different depending on whether it has been wired (strap-selected) for use with the laser subsystem or the RF subsystem.

2-2.4 Cueing

2-2.4.1 Introduction For the testing of force-on-force scenarios, it is of great analytical importance that human responses to combat conditions be replicated. There are several important categories of cueing, including "near miss" cueing of players who are targets in small areas. The initial prototype effort, relative to the player pack, will be only a single-tone emission device that produces a "beep" when one player is illuminated by another but is not "killed." The tone emitter will also be the means for notifying the player of his elimination from play in simulated combat by means of a continuous tone.

For the long term, development plans are in progress to define and prototype an integrated man-safe "flash-bang" area weapon cueing, indirect fire, with real-time casualty assessment for the FY 1980 time frame. BDM is working with agencies associated with the US Army-CDEC, Picatinny Arsenal, and others, to adapt the true near-term capabilities of existing hardware to TNF S^2 instrumentation.

A man in combat, as part of a larger system, is to be tested in as realistic conditions as subjectively possible, given constraints of cost, size, weight, power, and practicality. This man, as "part" of a system, accepts input stimulus and responds in certain ways. The testing, training, and validation of elicited responses of the man demand some replication of real-world stimulus (actual combat). Categorically, the man must react to several different classes of stimuli. The effect of a near miss of a high-velocity rifle bullet is surely different in character from a near miss by an artillery round or hand grenade. The effects of weapons' near miss on the actions of the man will be simulated in a rudimentary manner, initially, with room for growth both in realism and accuracy. Further development of sophisticated cueing will proceed after the prototype development phase.

2-2.4.2 Types of Cueing.

2-2.4.2.1 Small Arms Cueing at Target. The small arms cueing effects on a nontarget are those of an audible whistling sound of short duration. The tone emitter mentioned previously and in use on MILES and LWESS has proven effective in replicating the real effect.

2-2.4.2.2 Area Weapon Cueing at Target. The physical phenomena of a near miss by an actual artillery round or grenade cannot be replicated in safety. However, by coupling simulated effects - the man-safe "flash-bang" device - with the proper psychological conditioning (including pretest indoctrination), the simulation can then have a good degree of realism.

2-2.4.2.3 Vehicle Cueing - Internal and External. The weapons effects to strobes at Ft. Hood, while the internal cues to vehicle crew are the automatic stoppage of the vehicle and the explosion of the smoke grenade (which is mounted on a welded steel assembly added to the vehicle).

2-2.4.2.4 Fatality Cueing (Man and Vehicle). This function is used by existing force-on-force test instrumentation systems to insure that a player is indeed removed from further play in a scenario. The activation of an automatic shut-off system for vehicle engines (tor "mobility kills") and disablement of weapons (for "firepower kills") is being considered. The cueing peripheral device and/or universal I/O peripheral device on the player pack will provide a readily adaptable means of providing

2-2.4.2.5 Firer Recognition of Weapon Effects on Targets. The cueing of the results of a single shot or burst of fire has been considered important in Xerox's design of MILES. In platoon-level combat, the individual perception of the results of player actions has perhaps not been emphasized. But in the small forces involved in TNF S^2 testing, this factor may be very important, especially in low-visibility or low-ambient-light conditions. On a training-oriented system, a small strobe light flashes when a kill has been effected. At Ft. Hood, when a TOW missile crew kills a tank, red smoke and a flashing strobe announce their successful hit. A player's ability to perceive a weapon's effects and to move on to a new target (as would be the case in actual combat) will modify the tactics and resultant outcome of play. Again, the manpack has features which will enable the almost trivial implementation of visual cueing in some manner. The scoping of this task will be the subject of future design and planning.

2-2.4.2.6 Graded Response of Defense to Recognition of Threat. Even though weapon effects have problems being realistically simulated, there are other cues which can be provided accurately. These are the physical configuration of threat players, their weapon's appearance, and their strategy and tactics. The motivation of players and their response to the preception of a threat can be modified by the appearance of mockup or simulated enemy uniforms, behavior, language, and weaponry. For example, the recognition of a threat weapon, including the threat's effective range, and resulting quick targeting are necessary for defense survival. Failure to recognize a particular threat would result in modification of test results. As the prototype instrumentation development proceeds, the realistic cosmetic effects of the actual test can be planned and designed.

Although the ideas/methodology presented here are basic and cannot reflect the improvements in player cueing which experience in force-on-force testing will provide, the means for qualitative growth in this area is outlined.

2-2.4.3 Present Methods. MILES and LWESS utilize high-pitched tone oscillators to annunciate the "near miss" function of a laser illumination in simulated combat. MILES gives a single 2.5-second "beep" for a "miss within approximately 0.5 to 1.0 meters of the player, and gives a double beep when the illumination is closer but is not a "kill."

2-2.4.4 Prototype Development.

2-2.4.4.1 Direct Fire Cueing. The initial prototype-production cueing device proposed is a simple tone emission device. The particular device chosen will optimize size, weight, power, and function. The software device driver, resident in the ECS, is of at least equal importance to the operation of cueing. The player will be given subjective information on the relative closeness of a near miss, as well as basic kill cueing.

2-2.4.4.2 Indirect Fire Cueing. Area weapon cueing will be done by attempting to moderately replicate the sound of exploding small ordnance utilizing the same cueing device, but with a pulse/noise type of drive to the audio element

Manpack devices mounted in vehicles should cue the effects of bullets/rockets against armor as well as those envisioned for individual infantry.

2-2.5 Universal Input/Output Module.

The purpose of the univeral I/O modules is to enhance the flexibility of the player pack by providing two-way electrical communication with the outside world. Each module provides 16 digital inputs and outputs. The universal I/O modules will be plugged into the standard ECS buss.

On a human player, the universal I/O module would be used to control cueing devices and monitor posture. It could be used in the future to monitor blood pressure, heart rate, and other physiological variables as needed.

On vehicles, the I/O module would be used to control flash/bang/smoke cueing devices.

As a contoller for unique, test-specific equipment, the player pack could be used to activate television cameras and sense intrusion detectors. The player pack could contain more than one universal I/O module.

Each peripheral interface module will be equipped with a self-test feature, where both inputs and outputs can be checked by comparison to internally generated reference signals.

All the universal I/O module functions are described in detail below.

2-2.5.1 Digital Inputs. All digital inputs to the universal I/O module will be TTL-level. The inputs will be buffered and protected against voltages above +5 volts or below zero volts (ground), and against a voltage change rate greater than 500 V/sec. Each input will be addressable by ECS. All inputs will use shielded cable and connectors to minimize noise.

2-2.5.2 Digital Outputs. All digital outputs from the universal I/O module will be open collector-type driving transistors for good drive capability. The output transistors will have a breakdown voltage of 50 volts and a sink current of 50 mA at 1 volt. The outputs will also be protected against overload voltage and a voltage change greater than 500 V/sec. Each output will be addressable by ECS. All outputs will use shielded cable and connectors to minimize noise.

2-2.5.3 Addressing. To keep the I/O modules versatile, every module must be identical and still be addressed uniquely when plugged in to any of the peripheral buss connectors on the ECS buss. This will be accomplished by having a set of switches which determines the unique address of the particular I/O module. ECS will be able to test the setting of the address switches and determine if it is correct and that the correct module is being accessed.

Each input and output port of every I/O module will be addressed uniquely by ECS.

2-2.5.4 Power. There will be 5 power-supply voltages available from the dc/dc converters on the ECS mainframe to each I/O module. These voltages will be +5, ±12, and +28 unregulated. All the power-supply voltages will be available at the output pins of the I/O module to provide power or reference to external devices. These voltages will be used only when absolutely necessary so as not to drain the main ECS power source unnecessarily. These supply voltages will be current-limited on the I/O module to prevent external devices from overloading and "pulling down" the ECS power busses. Power conservation is important, and +5 and +28 volt supplies will be utilized wherever feasible. Each I/O module will have its own power-supply voltage regulators.

2-2.5.5 Self-Test Feature. The self-test feature will test all outputs and inputs for accuracy and issue the ECS a "go/no go" signal for each test. The self-test feature will perform three tests: Test on digital I/O's, power-on test, and addressing.

2-2.6 Direct Ranging Subsystem.

2-2.6.1 Functions. The direct ranging subsystem, if required, will be comprised of two elements. One element will measure the range from an attacking small arms weapon to the target player, and the second element will measure the range from a player to an exploding area weapon simulator. Both of these functions will utilize other subsystems to minimize circuit complexity. There functions are to be supplied by the contractor furnishing the laser weapon simulator. Details of these functions are given below.

2-2.6.1.1 Direct Ranging to Area Weapon Simulator. Simulators for area weapons (mortars, hand grenades) are being developed which will emit light (flash), noise (bang), and smoke when detonated. Any given player can measure its range from the detonation by measuring the time differences of arrival of the light and sound.

The light will be detected by the harness used with the laser weapon simulator subsystem. The light from the simulator will be differentiable from a laser pulse by its width (laser pulses are 150 ns wide, simulator pulses will be several milliseconds). When a wide pulse has been detected, the laser weapon subsystem will notify ECS through an interrupt. ECS will then start a range clock in the direct ranging subsystem and arm it to look for a sound pulse. The sound pulse will turn off the range clock and cause an interrupt to ECS.

This portion of the design must be closely tied to the simulator development. At present, it is unclear as to the best way to differentiate the sound pulse from background noise. Two possibilities are a threshold detection coupled with envelop attack and decoy characteristics, or having the simulator emit an ultrasonic tone.

2-2.6.1.2 Direct Ranging to Small Arms. One possibility of direct ranging to small arms would be the same as for area weapons. If this approach proves preferable, the only problem will be to discriminate between area weapon simulators and small arms. Ways of doing this should be investigated. This approach would probably be limited to ranges of 100 feet or less.

The second approach would be to use an RF pulser on the target to cause a laser pulse to be emitted by the attacking weapon.

In this approach, the target's ECS would decide it needed to measure range and would initiate a measurement cycle. The measuring subsystem would emit an RF pulse and trigger a high-speed range clock (probably the one contained in the transponder PL player handshake unit). A directional receiving antenna on the attacking weapon would detect the pulse and immediately emit a laser pulse. The laser detector harness on the target player would detect the pulse and stop the range clock.

2-2.6.2 Hardware Elements. The two types of direct ranging would operate at different speeds and require different supporting features from other subsystems. They might, therefore, be implemented as two separate peripherals.

The time difference of arrival subsystems would basically use other subsystems for everything except the actual measurement and the detection and differentiation of the sound pulse. They would interface with ECS to determine when a wide light pulse had occurred, would interrupt ECS when a subsequent sound pulse had been detected (or an overrange occurred), and would latch the measured time for ECS to read.

The RF-laser transponder would accept a command from ECS to do a measurement and transmit an RF pulse (simultaneously starting the range clock of the transponder PL handshake unit). The returned laser pulse would be detected by the laser harness. This would, in turn, stop the transponder clock and interrupt ECS that the data was ready.

2-2.7 Umpire Intervention.

The player pack carried by the umpire will be equipped with a hand-held terminal through which observations and interventions made by the umpire will be logged. His position and the time of day will automatically be calculated and stored with every entry.

The umpire will intervene in situations which cannot be handled directly via normal player pack operation (for example, two players coming close enough to each other to engage in hand-to-hand combat). The umpire would enter the player's identification and the umpire player pack will "flip a coin" and decide which player was disabled or killed.

The umpire will also carry a laser illuminator or designator that has a specific umpire code that will disable any player, vehicle, or equipment carrying laser sensors when illuminated. In the event that an umpire uses his designator on a target, the kill will be recorded as an umpire intervention in both the player's and the umpire's player packs. If alterations of the situation are necessary, the umpire will enter the information on his data terminal.

2-3 CONSTRAINTS AND LIMITATIONS.

Any instrumentation system designed for general purpose applicability has certain inherent limitations to its structure. It is the purpose of this section to spell out limitations of the TNF S^2 system and suggest ways in which they may be overcome in the future.

2-3.1 Position Location.

The LORAN-C position location system is a passive system in that use of the grid requires only a receiver. Consequently, an unlimited number of players may use the system simultaneously. However, the LORAN-C system has several shortcomings relevant to the general nature of TNF S^2 testing. LORAN-C is accurate to only ± 20 meters for a stationary player. In scenarios where deployment/tactics of small groups of foot soldiers are being examined, this is typically too coarse. This uncertainty in location becomes much larger for moving players and becomes nearly unusable for high-dynamic players (helicopters, aircraft, etc.) unless the system is aided by using motion sensors and Kalman filtering - both unsuitable for a manpack unit. Finally, and most restrictive, there is no control over the LORAN-C grid. In order to use it, the test must be conducted in an area that is covered. This restricts testing to the East, West, and Gulf Coasts of the U.S. and several other isolated areas. Internal areas of the U.S. and all of Europe are not properly covered.

One solution to the position location problem is to develop a second, high-precision PL system. This could be done by using the radio communication of two to five meters, even for high-dynamic aircraft. However, this solution also has problems. Specifically, the number of players would be limited to around 200 and the communication system repeaters would have to be carefully placed and maintained for each test. Additionally, there are problems of reflections, obstructions, and multipath associated with line-of-sight RF systems. However, it would allow the test to be conducted wherever desired.

A second potential future solution is use of GPS/NAVSTAR. This cannot be implemented until the satellite net is established and will require development of a GPS receiver module.

2-3.2 Determinism.

Because the players are all autonomous and the intelligence is distributed (for reasons described previously), there is no central repository of information to rely on for resolving conflicts. Conflicts arise primarily when simulators are used which cause results that could not happen with the "real thing." For example, a laser simulator for an M16 has a beam divergence which could, under certain conditions, allow more than one player to be illuminated by a single shot. With a live M16 this would be the equivalent of hitting two targets with one bullet -an unlikely situation. With a central computer/telemetry system, each player informs the central computer that he has been "hit" and by whom. The computer "knows" that only a single round has been fired and chooses one of the "hit" players as a victim. With a distributed system, the information that more than one target has been "hit" is not available to the players. Since each autonomous player must independently compute the probability that he was "killed," the restrictions on the simulators used are more strict. Essentially, this means that the simulators themselves must be configured to minimize such conflicts.

The overall consequence of distributed autonomous players is that probabilistic calculations must be more rigorous than previously necessary. This impacts the requirements placed on the simulator equipment: (1) it must supply the target system with more information about the firer than was previously needed in order that the data required by the more rigorous calculation be available, and (2) the simulators themselves must exhibit a high degree of realism.

The total overall realism of any test will be limited by the degree of realism exhibited by the simulation devices and methods employed.

2-3.3 Real-Time Casualty Assessment.

The RTCA process determines probabilistically whether an engaged player (target) has been missed, wounded, or killed as a result of being "fired upon." There are two basic weapon categories involved -LOS (line-of-sight) weapons (rifles, etc.) simulated with laser, and explosives (grenades, mortars, etc.). There is an RTCA task for each category.

2-3.3.1 Line-of-Sight Weapon RTCA. The attention to detail required for this algorithm is greatly influenced by the scenario involved. For example, with battalion-size forces one can be fairly crude, since one player more or less makes little difference. However, for the small forces typical of TNF S^2 scenarios, one player could easily be ten percent of the entire force. Consequently, a great deal of attention must be paid to details which, in the past, have been known to influence the results but were difficult to incorporate. Lethality models from TSEM will be combined with results from CDEC and AMSAA to produce RTCA algorithms germane to the TNF S^2 scenarios. These will incorporate at least the following variables: range, firer posture, marksmanship level, weapon type, round type, and firing mode. At the target the variables will be posture, armor, and shielding. Figure 19 shows the various human body areas that must be considered (vehicles can be handled analogously). In each body area, the probability of a kill, given a hit, is the same. This probability changes from area to area. Each body area must be equipped with laser sensors, the number of sensors being proportional to the probability of a hit, given a pairing, on that body part. Player shielding effects arise from the use of protective cover (foxholes, trees, etc.). For a shielded player the probability of a kill, given a hit, is unchanged, but the probability of a hit, given a pairing, is considerably

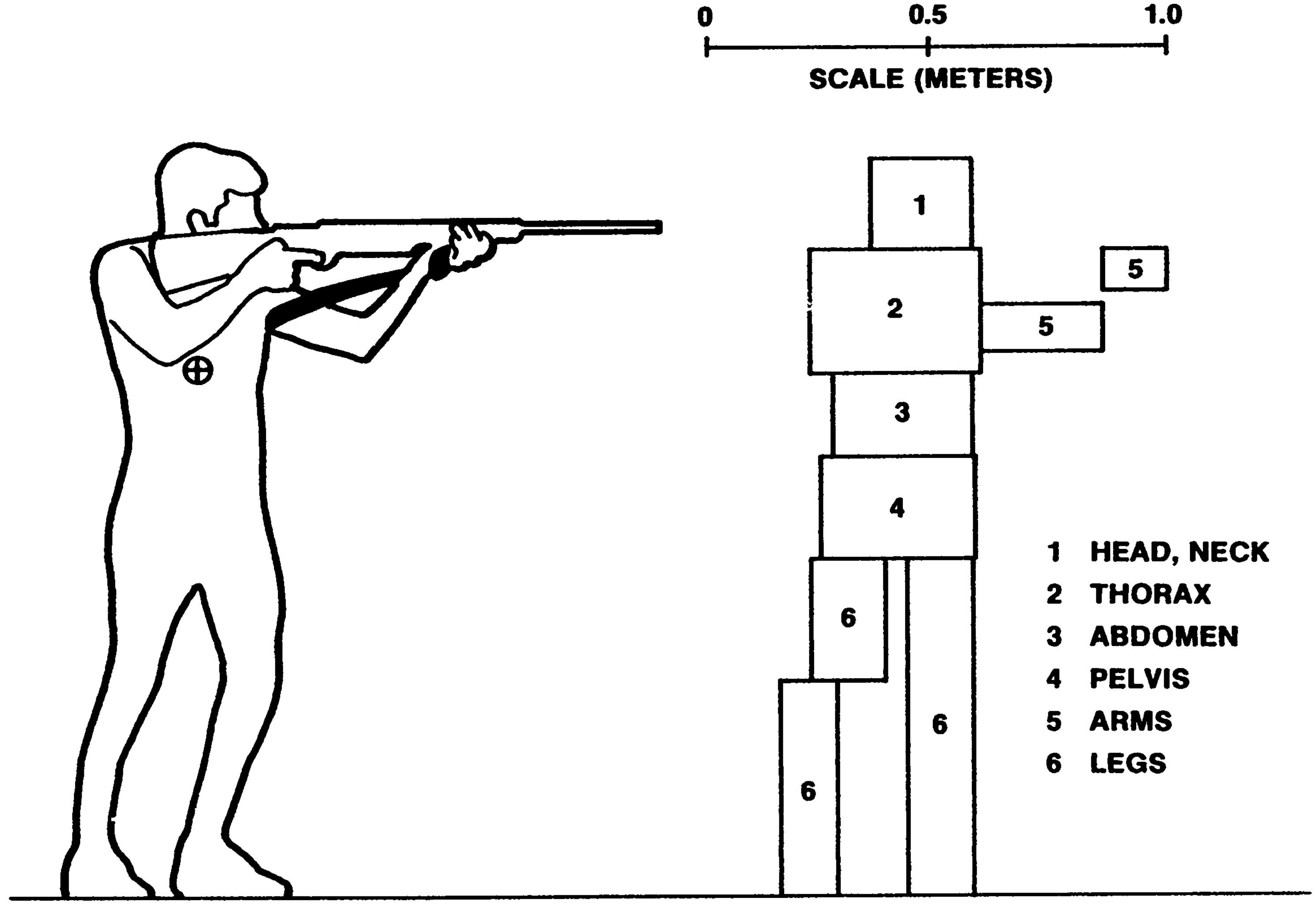


Figure 19. Typical body areas for RTCA sensors.

reduced, as shown in Figure 20. The presence of shielding can be inferred by the pattern of the sensors which are illuminated. Incorporating shielding effects into the RTCA calculation requires that all sensors be independent so that the pattern can be determined, and may require that a greater number of sensors be used than otherwise. These data requirements also impact the capability of the laser weapon simulator. It must be able to transmit the variable player data in addition to the normal fixed data.

2-3.3.2 Explosives and Indirect Fire RTCA.

Explosives and IDF (indirect fire) have caused great difficulties in simulation exercises since their beginning. The problem does not lie with lethality models and computation of kill probabilities as much as it does with inadequate simulators. The basic kill probability models use a "cookie cutter" approach. That is, if a player is unshielded and within the lethality radius of an exploding round, he is "killed." Consequently, the RTCA algorithm must know (1) the location of the point of the explosion (to determine distance from the player), (2) the round type (to determine kill radius), and (3) whether or not the player is shielded from the effects of the explosion.

There are two approaches to this problem: software only and hardware simulators. The software approach is complex, unrealistic, provides no player cueing, but is safe. The simulator approach is comparatively uncomplicated, very realistic, provides very good player cueing, but has been plagued with personnel safety problems.

2-3.3.2.1 Software Simulation. Indirect-fire software simulation requires the use of a central computer, a communications link, and a highly accurate position location system (two to five meters). Basically the simulation operates as follows: the central computer "fires" a round and computes its impact point (cannot be used for hand grenades). It then transmits the impact coordinates and kill radius to all players.

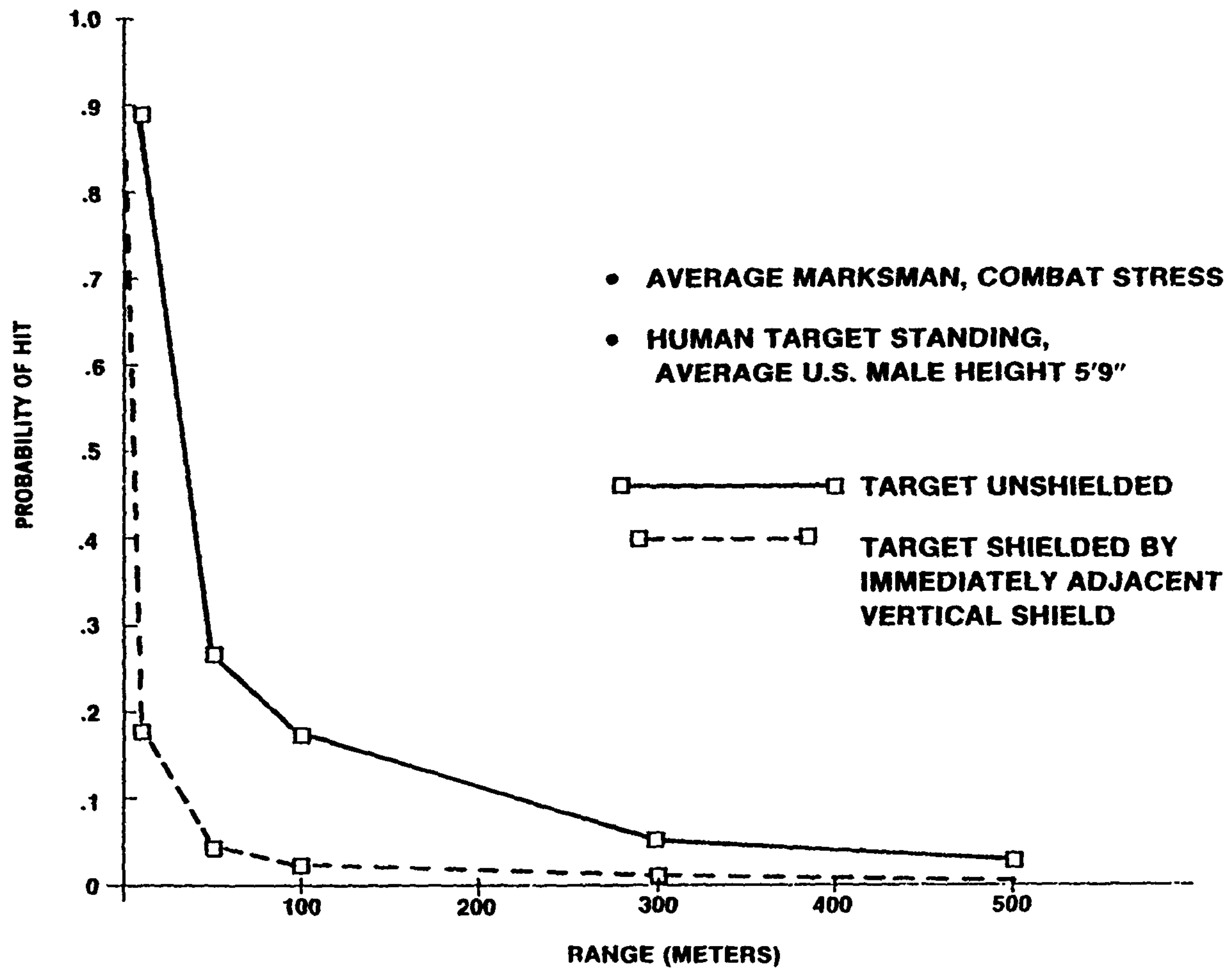


Figure 20. Probability of hit example.

Those within the kill radius transmit their position to the computer. The computer relates the position of each affected player to all objects on a digitized map (including mobile objects - vehicles) which could shield the player. If the player is unshielded, he is notified that he is "dead."

As the number of players and vehicles increase, this process becomes unwieldy and the response time increases.

2-3.3.2.2 Hardware Simulation. Hardware explosive simulators typically operate on the "flash-bang" principle. That is, they emit a flash of light and an audio noise (bang). In this respect they provide all the requisite player cueing of a live round. Distance to the explosion is determined by equipment on the player measuring the relative times of arrival of the light flash and the bang. The laser sensors can be made to detect the flash, and appropriate audio sensors detect the bang. The probability of kill algorithms are the same as the software-simulated algorithms.

The problem has always been that of finding a way to construct a "flash/bang" simulator that has the ballistic characteristics of the real round and yet is still personnel-safe. This problem is discussed in detail in the simulator development section of this report.

SECTION 3
WEAPON EFFECTS SIMULATION

3-1 INTRODUCTION.

Previous sections of this report have dealt directly with methods of instrumentation. Here we will focus attention on the actual phenomena to be simulated in a force testing environment. We will classify some of the more significant characteristics and show their importance to force-on-force testing. Two general classes of weapons to be simulated are direct-fire weapons and indirect-fire weapons. Table 8, "Weapon Characteristics Overview," shows the major divisions in the types of weapons to be instrumented.

3-1.1 Direct-Fire Weapons (Upper Table 8).

Direct-fire weapons are defined to be weapons aimed at a target on an approximate straight-line path. Their primary use is against targets seen by the firer. There are exceptions, such as "plunging fire," but the emphasis is on the main usage of what can be termed "point" weapons. A point weapon is defined, in our application, as one whose primary effect on a target is due to the kinetic energy of its projectile upon striking that target.

3-1.2 Indirect-Fire Weapons (Lower Table 8).

Indirect-fire weapons are defined to be weapons aimed at a target by means of a characteristic parabolic (ballistic) path. More simply, indirect-fire weapons are those aimed indirectly. They typically employ explosive projectiles; consequently, their primary use is against targets requiring more lethal area coverage than that provided by "point" weapons. Often, targets are not visible to the indirect-fire weapon crew, and their projectile's effects are spread over several square meters. Some "area weapons" such as the M-79 or M-203 are often used against "point" targets, but for the purpose of the instrumentation development they are considered indirect-fire, area-projectile-effect weapons.

Table 8. Weapon characteristics overview.

DIRECT-FIRE WEAPONS

SIMULATOR-WEAPON TYPE	REPLICA FUZING	REPLICA APPEARANCE*	MAX EFFECTIVE RANGE	INSTRUMENTATION RANGING METHOD	TARGET WEAPON EFFECT DISCRIMINATION
Infantry Rifle	N/A	2-3	500 m Range	Laser/RF/PL	Aimpoint Sense
Small MG	N/A	2-3	500 m Range	Laser/RF/PL	Aimpoint Sense
Large MG	Not Used	2-3	2000 m Range	Laser/RF/PL	Aimpoint Sense
Pistol	N/A	1-2	25 m Range	Laser/EO/Acoustics	Aimpoint/Simple Designation
ATGM	Not Used	1	3000 m Range	Laser/RF/PL	Aimpoint Sense
12 Ga. Shotgun	N/A	2-4	25-150 m Range	Laser/RF/PL	Aimpoint Sense

INDIRECT-FIRE WEAPONS

SIMULATOR-WEAPON TYPE	REPLICA FUZING*	REPLICA APPEARANCE*	(DELIVERY RANGE) LETHAL RADIUS	PROJECTILE EFFECTS RANGING METHOD	WEAPON EFFECT DISCRIMINATION
Hand Grenade	1-2	2	(40M) 3-10 m Radius	EO/Acoustics	Area Designator/ Optic Shielding
Grenade Launcher	2-3	2-3	(200M) 10-30 m Radius	EO/Acoustics	Area Designator/ Optic Shielding
Mortar	2-4	1-2	(XKM) 30 m Radius	EO/Acoustics	Area Designator/ Optic Shielding
Mine AP/AT	3-5	1-2	(-0-) 50m Claymore	EO/Acoustics	Modified Sector Designator
Artillery	4-5	5	(XKM) 50 m Radius	EO/Acoustics	Area Designator/ Optic Shielding

*Rating of relative importance (1 to 5): 1 = most important, 5 = least important.

Abbreviations:

- MG - Machine Gun
- EO - Electro Optical
- RF - Radio Frequency Transponder Range Technique
- PL - Position Location Derived Range Technique
- ATGM - Antitank (Wire) Guided Missile
- AT - Antitank
- AP - Antipersonnel
- N/A - Not Applicable

References:

JMEMS/SS - Joint Munitions Effectiveness Manual/Surface to Surface
FM20-32-Mine Warfare
Real-Time Casualty Assessment Handbook
(RTCA), 1 Aug 1977, BDM/SSL-DLM-0990-77 CONFIDENTIAL
James Infantry Weapons - 1976
Soviet Special Operations Scenarios I & II (U) SECRET
BDM/W-0666-78-S, March 1978

3-1.3 Weapon Types (Left Column, Table 8)

The types of weapons to be simulated, as listed in Table 8, were selected because of the arsenal available to both attack and defense forces. The weapon complement of defense forces is known, and Figures 21 and 22 show the makeup of an aggressor motorized rifle battalion, including its weapons. For example, a LRRP (Long Range Reconnaissance Patrol) team will have its genesis in this type of organization, and the figures are shown to present an idea of the array of equipment available to a LRRP team commander, not including air or water transportation. Satisfying the instrumentation requirements for these weapon types will provide an adequate representation of the spectrum of weapons available for use in a terrorist scenario.

The following will be divided into a discussion of direct-fire and indirect-fire characteristics, all referenced to Table 8.

3-2 DIRECT FIRE.

3-2.1 Direct Fire - Simulator Type

The rifles and machine gun simulators will be the genuine articles with a laser and other required circuitry attached. The weapons will be modified to the minimum extent possible. The pistol simulator, however, may require complete design and production (i.e., the incorporation of an actual weapon into the simulator may not be possible). International Laser Systems, Orlando, Florida, has proposed to do a detailed study of the feasibility of retro-fitting a pistol with a laser in a realistic manner, but this remains for future development.

The ATGM (antitank guided missile) is a weapon representative of an armor-piercing capability that many armies possess. It is man-portable and accurate. The range shown would be the maximum for this class of weapons. A man-pack version ATGM has a range of about 1 km.

The 12-gauge shotgun is in use by military guard forces in several applications. The weapon could be replicated in a manner similar to that of the rifle. Its characteristics would be coded into the weapon and target instrumentation, as appropriate.

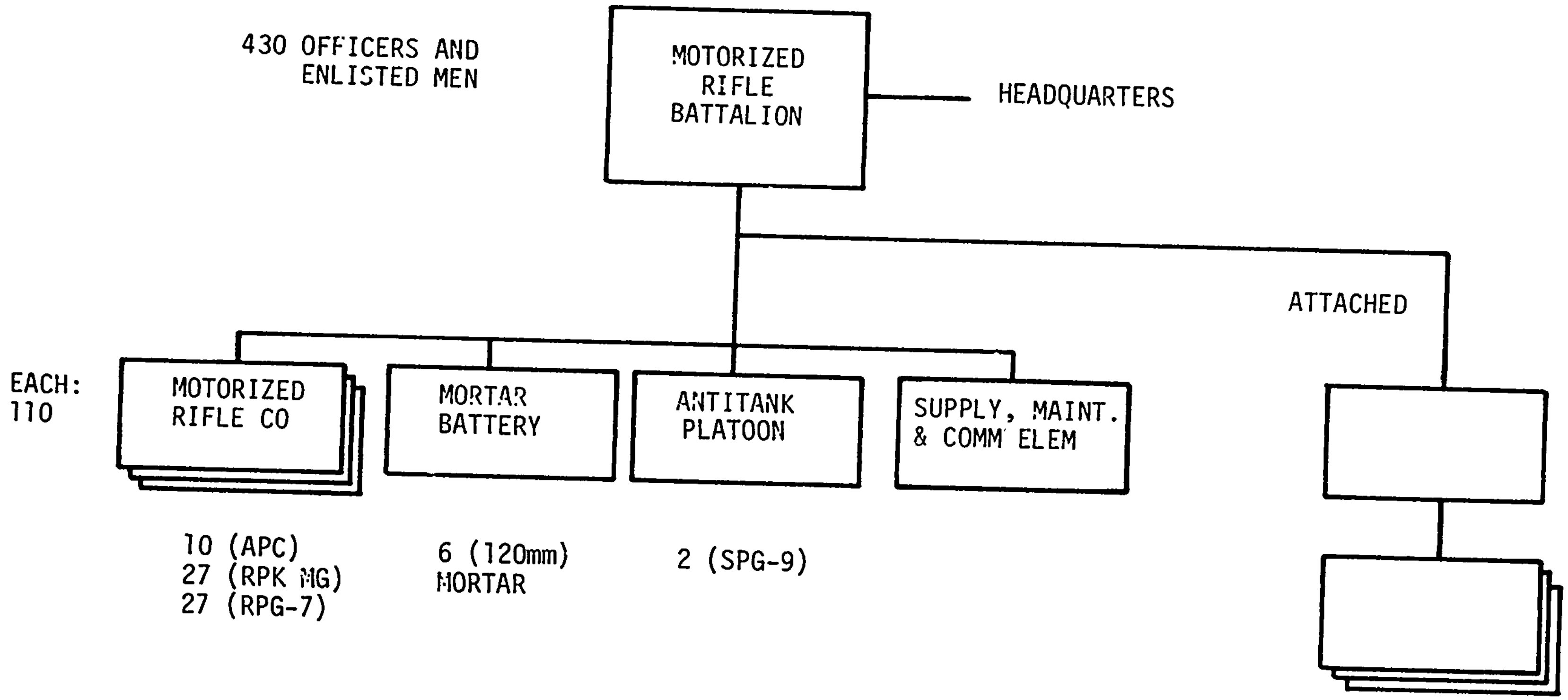
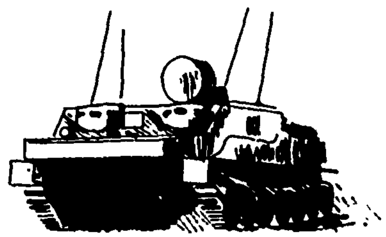


Figure 21. Threat battalion organization.



BTR 50

BTR 60

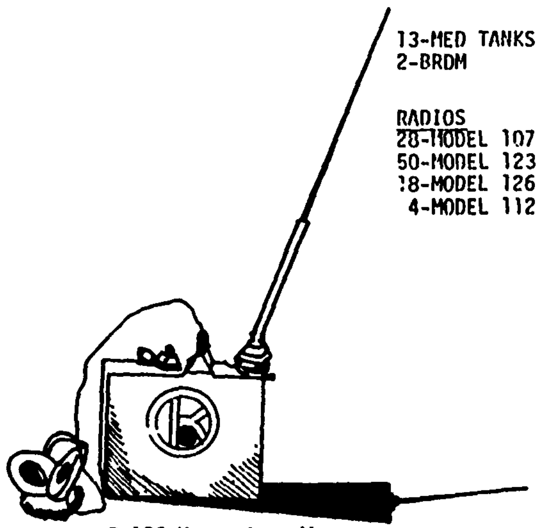
KEY EQUIPMENT

(NUMBERS DEPENDING ON FINAL AGGRESSOR ORGANIZATION)

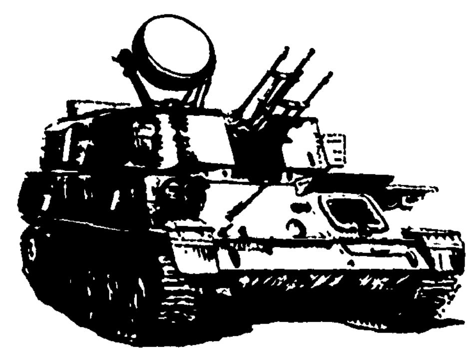
31-APC	30-SGM HEAVY MACHINE GUN
6-120-MM MORTAR	2-SPG-9 RECOILLESS AT GUN
27-RPK MACHINE GUN	27-RPG-7 AT GRENADE LAUNCHER
	6-SAGGER MANPACK ATGM

AUGMENTATION

13-MED TANKS	6-ZSU-23/4
2-BRDM	9-122-MM HOWITZERS
RADIOS	TRUCKS
28-MODEL 107	5-GAZ66
50-MODEL 123	3-ZIL/URAL
18-MODEL 126	1-VAN
4-MODEL 112	1-POL
	1-MAINT
	ASSTD-TRAILERS



R-126 Manpack radio



23MM SPAA Gun ZSU 23-4

Figure 22. Motorized rifle battalion.

3-2.2 Direct Fire - Fuzing.

These weapons depend primarily upon their projectile's kinetic energy to disable a target. There are armor-piercing and explosive rounds for some of the weapons, but the basic coding of weapon and target characteristics will be based on the most frequently used loads. The HEAT (high explosive antitank) round of the ATGM can be replicated adequately by sensing the angle of obliquity, without special fuzing replication. This angle drastically affects an armor-piercing round's effectiveness.

3-2.3 Direct Fire - Replica Appearance.

This section of Table 8 refers to the relative importance (1 - most, 5 - least) of the appearance of a particular weapon simulator in terms of its cueing value. The rating reflects the consideration of (1) the probable employment, (2) the relation of the size to its effective range (that is, can it be seen by its probable target under normal employment circumstances), (3) would a defensive patrol potentially discover a fire team equipped with one of these weapons, and (4) the differences in effective range of various weapons during an assualt operation.

For example, a squad under attack should fire first on the weapon presenting the greatest threat. Failure to incorporate threat recognition and response into the test scenario will severely reduce the credibility and usefulness of the test results.

3-2.4 Direct Fire - Effective Range.

This parameter describes the maximum range over which a laser must transmit data. It also affects the limitation on laser illumination spot size, the optimum sensor configurations, laser emitter optics, and many other engineering considerations. Candidate laser/sensor system vendors have a great deal of experience and data available for optimization of TNF S^2 instrumentation to replicate direct-fire weapons. The ranges defined in this column of Table 8 will prove to be no problem, excluding such variables as smoke, haze, rain, and snow. Reduced visibility conditions will, of course, limit range, but the rationalization is that the simulators are to transmit the beam to an observed target, so the congruent limitations of range and visibility should pose little problem.

3-2.5 Direct Fire - Instrumentation Ranging Method.

The reference in this column of Table 8 is to the ranging method to be used, which is mainly dependent on the desired distance of data transmission.

The long range of direct-fire weapons demands compatible range communication - longer than acoustic techniques are capable of. The Laser/RF/PL designation refers to a laser-initiated process on the targeted player whereby the range from the point weapon is derived from RF propagation delay ("a direct ranging" method) or from the positions (PL) of both the target and firer. The engineering and use of these techniques are discussed in detail in Section 2-2.6 of this report.

3-2.6 Direct Fire - Target-Weapon Effect Discrimination.

This column lists the methodology for sensing the relative aimpoint or illumination area of a directly aimed weapon. Because of the physical limitations on the pistol configuration, aimpoint sensing such as that used for the rifle laser designator may not be possible with the pistol. To keep it a realistic size, smaller optics may be necessary. A simple designation initiating a simplified Monte-Carlo RTCA algorithm should meet the needs of simulating pistols in a test.

3-3 INDIRECT FIRE.

3-3.1 Indirect Fire - Simulator Type.

Indirect-fire weapons are the most difficult to both simulate and integrate into the instrumentation system. The critical characteristics are the flash and sound of the bursting projectile and determination of its effect on the target. Also to be considered are the sound of a firing weapon and the area effects of CBW (Chemical-Biological Warfare) projectiles.

3-3.2 Indirect Fire - Replica Fuzing.

Three general classes of fuzes are hand grenade, contact, and proximity. The hand grenade fuze might properly be an M205-A2 fuze which, according to a telecon with Rock Island Arsenal, has no detonator, but is a simple "quick match" device for use with practice smoke grenades. The contact fuze (for mortar and rifle grenade use) would be a simple inertial contact assembly, used with a commercial flash cube assembly (discussed later in this section). The proximity fuze for artillery use would also be integrated with the flash cube assembly and would operate within several feet of the earth or a metallic object, as appropriate, after arming. The proximity fuze is a growth option and is mentioned in the interest of completeness.

The inherent characteristics of the fuzing of various area weapons affects the tactics of their use. In actual combat, hand grenades may be employed to defeat targets not approachable by other means. The weapon simulator should reflect these characteristics. The hand grenade simulator should then be fuzed with similar, if not identical, assemblies to those of actual weapons. Other weapon types have a similar deterministic relationship to the player packs, and their characteristics should be investigated and defined, and then replicated by instrumentation to the degree that safety will permit.

3-3.3 Indirect Fire - Replica Appearance.

The indirect-fire weapon simulator's appearance is important in the factors of force testing realism and tactics sensitivity analysis. The closer a weapon simulator is to the area of force testing, the more important its appearance in general. The rating reflects the relative importance of the appearance of a particular projectile launch device (or grenade). The rating of the weapon types reflects the following considerations:

1. The probable employment.
2. The relation of the launcher's visible range to its effective delivery range (that is, can it be seen by its probable target under normal employment circumstances).
3. Would a defensive patrol potentially discover one of these weapons?
4. The differences in the effective range of various weapons during an assault operation.

For example, a squad on perimeter patrol should attack recognizable threat mortar or ATGM emplacements. The threat simulators and crew should be realistic in appearance. The failure to recognize the threat and its characteristics could result in poor credibility of a test outcome.

This discussion comes under the general category of cueing, which is included in Section 2-2.4 of this report.

3-3.4 Indirect Fire - Delivery Range and Lethal Radius.

The figures for delivery are approximate and are included to show the individual weapon's probable location relative to the target.

The lethal radius given for each projectile type is also approximate and represents the worst case range so far as the instrumentation simulation of the effect is concerned. The maximum lethal radius of interest (for nonnuclear weapons) is abcut 50 meters.

3-3.5 Indirect Fire - Projectile Effects and Ranging Methods.

Lethal radius (distance) will be measured by utilizing the combined effects of light and acoustic emission given off by a very low-mass, low-velocity, man-safe projectile. The electro-optical/acoustics projectile effect simulation technique consists of the use of a flash cube, small battery, minute powder charge (toy "caps"), and styrofoam ball to replicate area projectile detonations. The peculiar light emission will uniquely trigger special audio ranging circuitry on the player. The unique acoustic emission of a specially designed gas generator will determine the range from the player by means of the measurement of the propagation of the wave in air. The specular characteristics of the device will be governed by a gas generator and orifice. Weapon type and category can then be uniquely coded for use by the player pack processor.

The processing of the data on the player is discussed in greater detail under direct range measurement, in Section 2-2.6 of this report.

3-3.6 Indirect Fire - Weapon Effective Discrimination.

The indirect-fire simulator projectile can be coded for several types of weapons. The specific limitation on coding and the engineering involved are to be the subject of future study. The requirements for the amount of discrimination between various projectile types can be defined later. It is sufficient to say that some discrimination is required and that a method exists to handle it. During the course of this report, we have coordinated with CDEC contractors studying the problem of indirect fire.

3-4 WEAPON SIMULATOR SYSTEM INTEGRATION.

The information about weapon peculiarities, chiefly probability of kill versus range, is coded in the player packs. The same audio-visual cues that aid realistic player reactions will also be used to convey data regarding weapon type to the player. The development and coding of these cues on weapon simulators, together with the detection interface design for the player pack, will be the bulk of the activity with respect to cueing, indirect fire, and weapon simulator development without the artificial intervention of an umpire during a war game. The combining of realistic visual and aural cues with instrumentation on a player will effectively integrate the function of several artificial approaches to indirect-fire area weapons. The use of audio and light coding techniques for close-range combat direct-fire simulation will utilize the same measurement techniques required for indirect fire. This will demand the development of weapon simulators which are nonelectronic themselves, and will be the subject of field testing to assure reliable operation with the player pack sensors.

The development of these weapon simulators is the most cost-effective solution to the problem of close-in direct- and indirect-fire real-time casualty assessment. The cost-effectiveness arises from the adaptability of TNF S^2 modular instrumentation to new and varied weapon characteristics and cueing requirements.

SECTION 4
INSTRUMENTATION DEVELOPMENT PLAN

4-1. INTRODUCTION.

The objective of this effort was to identify the optimal TNF S^2 test instrumentation needed to satisfy the test analysis and evaluation requirements of force-on-force, free-play testing using real-time casualty assessment. This was the first step in a program designed to provide a portable, mobile, many-player instrumentation system for the TNF S^2 program. At the onset there were two general program alternatives: (1) a sequential process in which the program issues and test concepts are formulated followed by instrumentation development and procurement, or (2) a concurrent program in which the instrumentation is developed and procured in a near-parallel path with the issues and test development process.

The sequential program appears initially to offer a minimum risk approach. However, since the development and procurement of instrumentation is an 18 to 24 month process, the sequential approach could introduce considerable delays into the actual field testing schedule. This lengthening of the process would also have increased cost implications.

A parallel program offers a shorter route to the desired TNF S^2 goal of issue resolution by field testing with no essential change in risk or cost. This can be done because the general nature of the TNF S^2 issues have been identified. In addition, test concepts have been developed sufficiently to permit the scoping of requirements for TNF S^2 test instrumentation.

The concepts to be implemented in the development of the TNF S^2 instrumentation have been based on the premise that future refinements in the program issues and test concepts will have little effect on the test instrumentation. What may change are the scenarios under which the tests will be conducted and specific issue-related event data. These changes do not impact the basic instrumentation requirements, but do affect the sensors used in data collection. These sensors are but a minor portion of the overall instrumentation costs.

Initial examinations of instrumentation requirements for TNF S^2 testing have not shown a need for a new testing methodology. The identified requirements, which span a wide spectrum of possible TNF S^2 test scenarios, do show a need for standard instrumentation concepts with a new approach to the employment of these concepts. The TNF S^2 instrumentation must be truly portable, must not require extensive field support personnel, and in some cases must be secure from outside monitoring. The thrust during the early development will emphasize the application of existing, off-the-shelf, technologies (e.g., RF transponders microprocessors) to minimize development risk.

The basic philosophy utilized during the conceptual development effort centered around a system that is modular, flexible, and expandable. The backbone or permanent part of each player unit will consist of a microcomputer, power supplies, power conditioners, and connectors to the various functional elements. This part of the player instrumentation is called the Executive Control System. Because it is a software-controlled element, with each of the player functions acting as peripheral devices, it will be truly flexible and expandable.

A modular approach was utilized in the design of the player functional elements. This will allow hardware and software tasks to be performed in parallel under this proposed effort. The various functional elements are: (1) weapon simulation, (2) weapon detection, (3) data logging, (4) position location, (5) cueing, (6) acoustic detection, (7) RF communications, and (8) hardware/software development system and the field O&M and quick-look systems.

The development approach utilizes many off-the-shelf components (microcomputers, RF transreceivers, laser transmitters, etc.) with minimal modifications. This approach was chosen to minimize development risk and time. The result is an instrumentation system that meets all of the

TNF S^2 testing requirements but does not meet the desired human factors of size and weight. Today's VLSI (very large-scale integration) technology is capable of reducing many of the planned player pack functions from a printed circuit card to a single component. This miniaturization could reduce the entire player pack from a range of 5.4 to 6.8 kilograms to a range of .9 to 2.3 kilograms, and from 5243 cubic centimeters to about 1229 to 1638 cubic centimeters.

To implement this type of circuit reduction at the program's onset would add considerable risk in both cost and schedule. This task will be addressed during FY 81 after the basic system has been fielded and thoroughly checked out.

4-2 DEVELOPMENT SCHEDULE AND TASKS.

The Instrumentation Plan follows a primary or baseline approach, using LORAN-C for the initial position location system. This approach minimizes both schedule and cost risk factors and will provide for early field testing. The proposed effort also identified a parallel task to improve the position location accuracy, utilizing transponder techniques. The packaging concept is designed to provide for a direct replacement of the hardware units. This parallel path does require development and would add additional risks to the overall schedule if it were the primary system. Any risk is minimized by the BDM approach, and a high probability of success is assured. Figure 23 illustrates the overall development schedule and Figure 24 shows the FY 79 key milestones.

Parallel development of the functional elements will be accomplished during the first year's effort, with laboratory demonstrations planned during the third quarter. Figure 25 illustrates the detailed schedule for the systems integration efforts to be performed in FY 79. A key factor in meeting the overall schedule is the timely acquisition of the hardware development system. This system is required at an early date to allow parallel efforts in both hardware and software development. The schedules shown in Figures 23 and 24 have utilized 1 February 1979 as the delivery data for this system. Any extension will undoubtedly cause a direct extension or delay to the overall milestones.

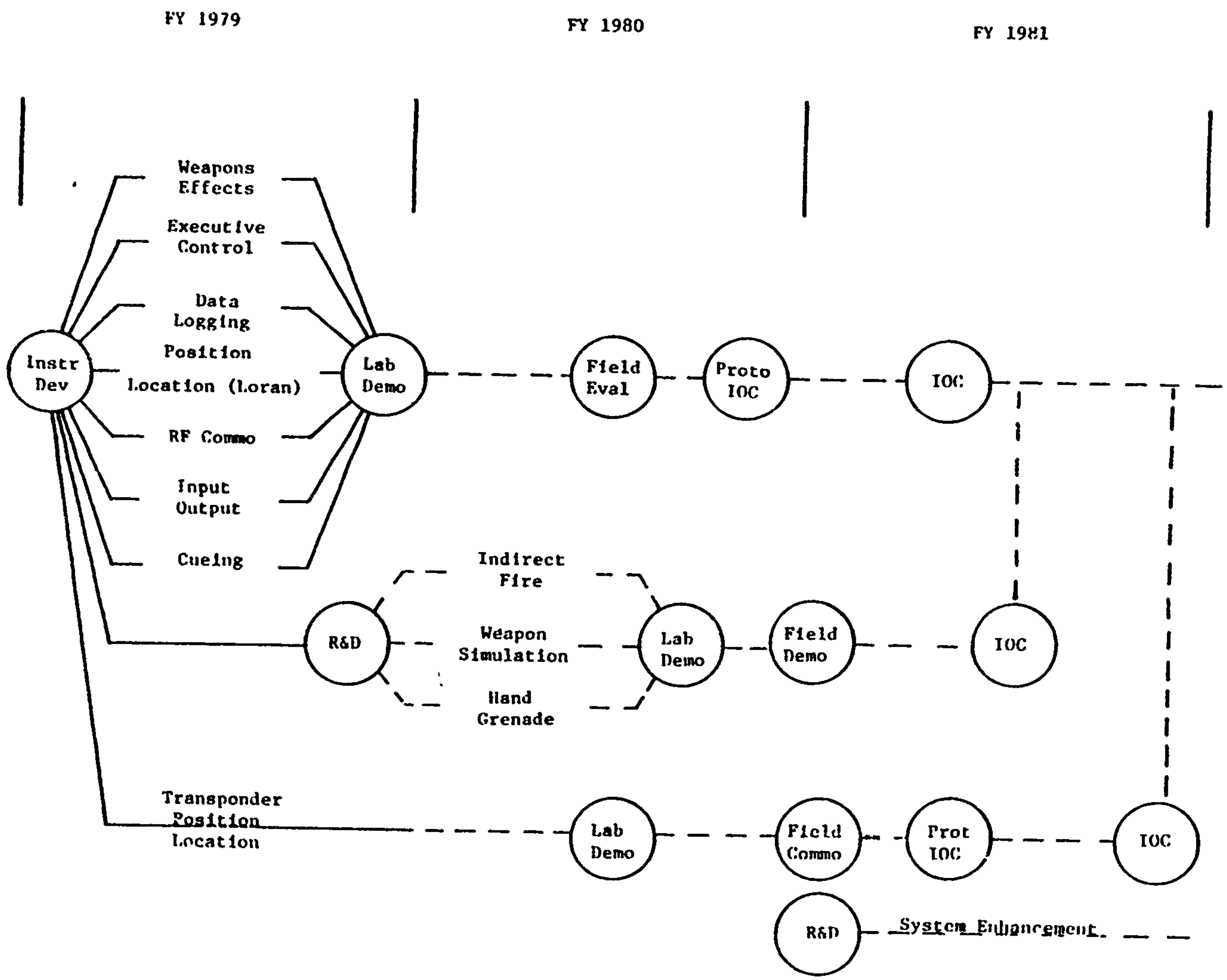


Figure 23. TNF S^2 instrumentation development master schedule.

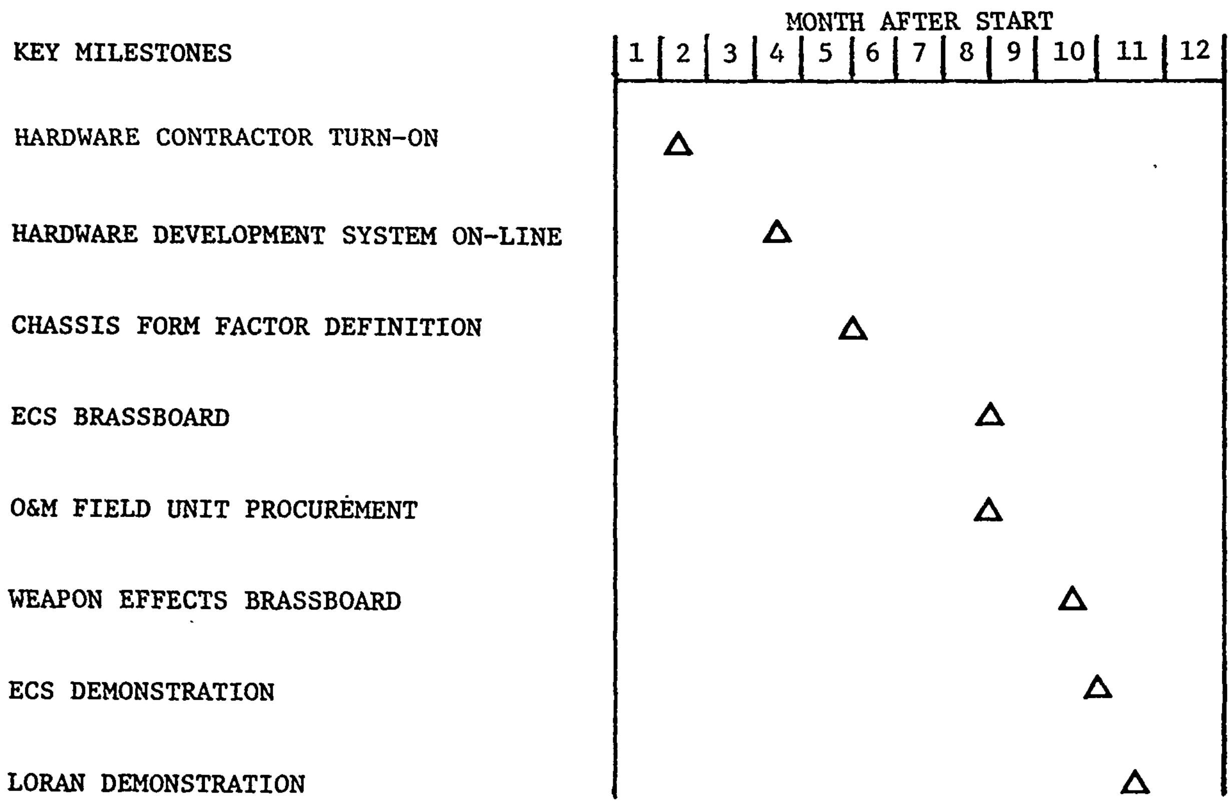


Figure 24. Key instrumentation development milestones.

4-2.1 Development Team Approach.

A team approach, utilizing members each with known areas of technical expertise, will be used in the development of the TNF S^2 instrumentation. The following participants have been identified for those areas shown in Figure 25.

Member		Responsibility
International Laser Systems	-	Laser Transmitters
	-	Laser Sensors
	-	RF Encoder/Decoder
	-	Weapon Simulator
Missouri Research Labs	-	PCB Fabrication and Assembly
Teledyne Systems Company	-	LORAN-C Receivers
	-	Packaging
	-	Software Design
Texas Instruments	-	Hardware Development Systems
	-	Microcomputer
The BDM Corporation	-	System Integration
	-	Digital Logic Design
	-	Software Design
	-	Packaging
VEGA Precision Laboratory	-	RF Receivers/Transmitters

4-2.2 Development Cost Estimates.

Table 9 tabulates the estimated instrumentation development costs. The costs are presented for each major function of the proposed system for each stage of development: brassboard, prototype and preproduction. These costs were estimated following lengthy discussions with recognized vendors. The estimates are based upon vendor costs or estimates, government publications, or the procurement costs of similar instrumentation. A summary of the estimated development cost for 15 prototype units and 50 preproduction units, together with the LORAN-C and transponder position location systems, is shown in Table 10. These costs do not include system improvements, hybridization or specific issue-related instrumentation development costs.

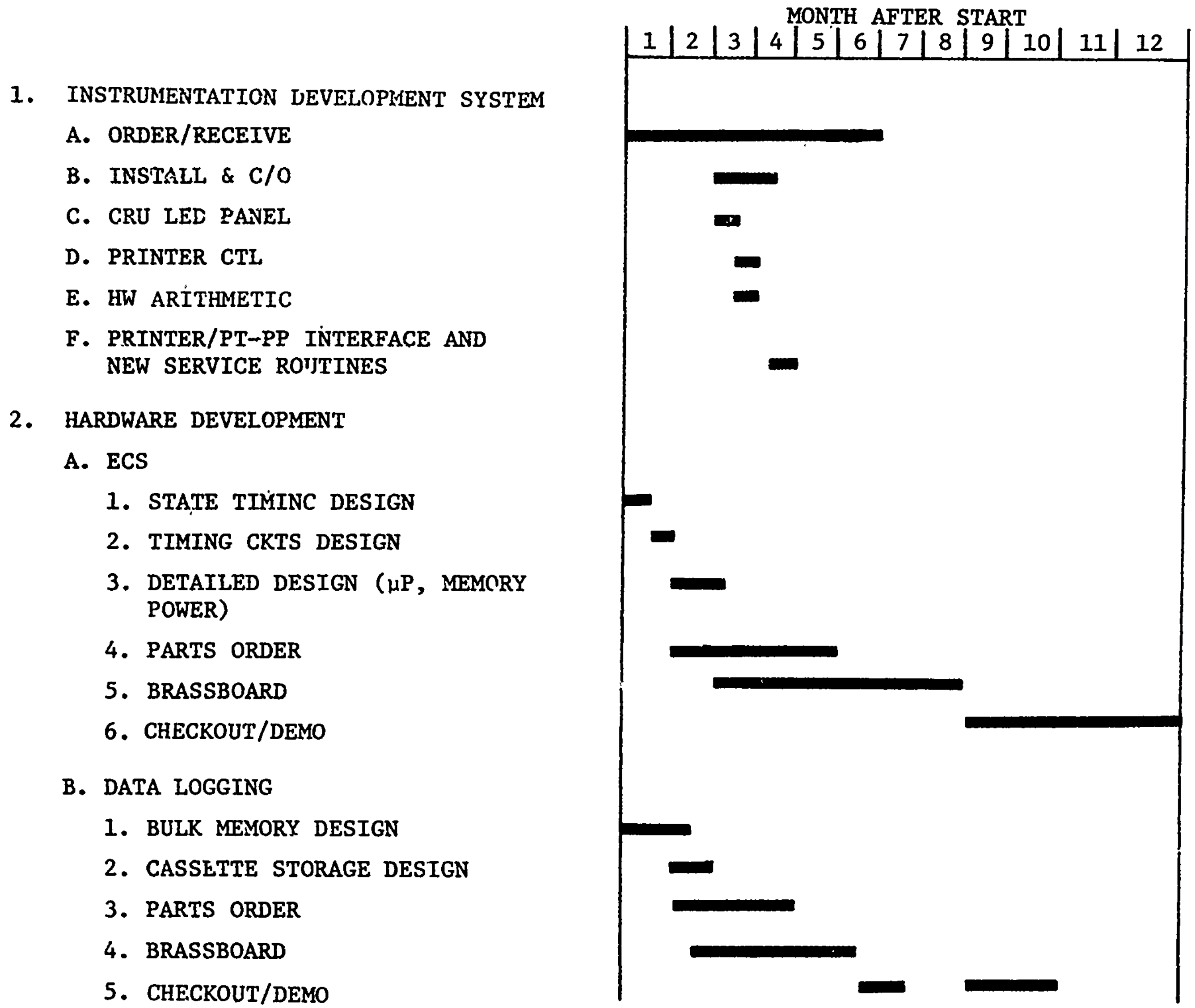


Figure 25. Detailed FY79 development tasks.

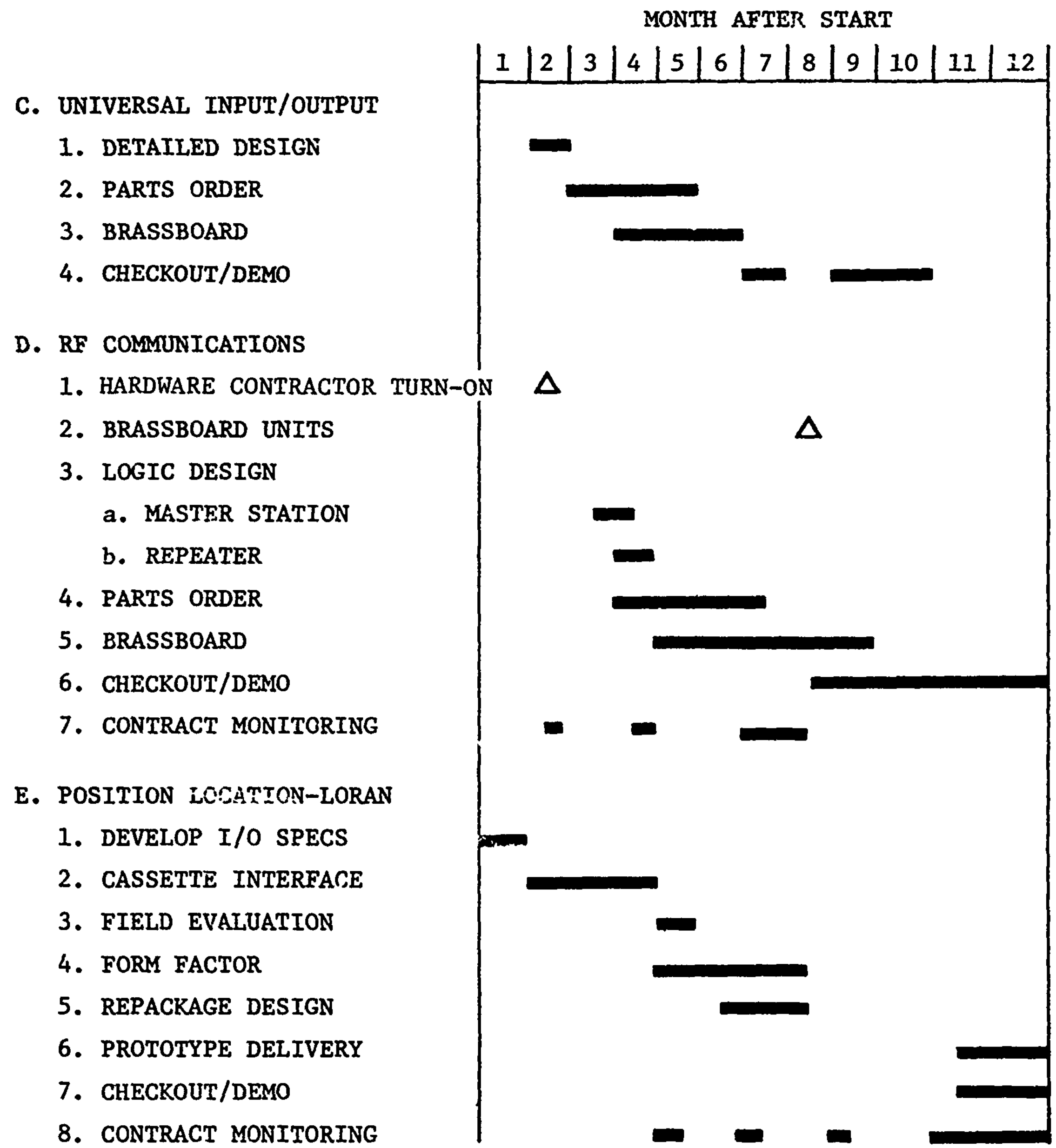


Figure 25. Detailed FY79 development tasks (continued).

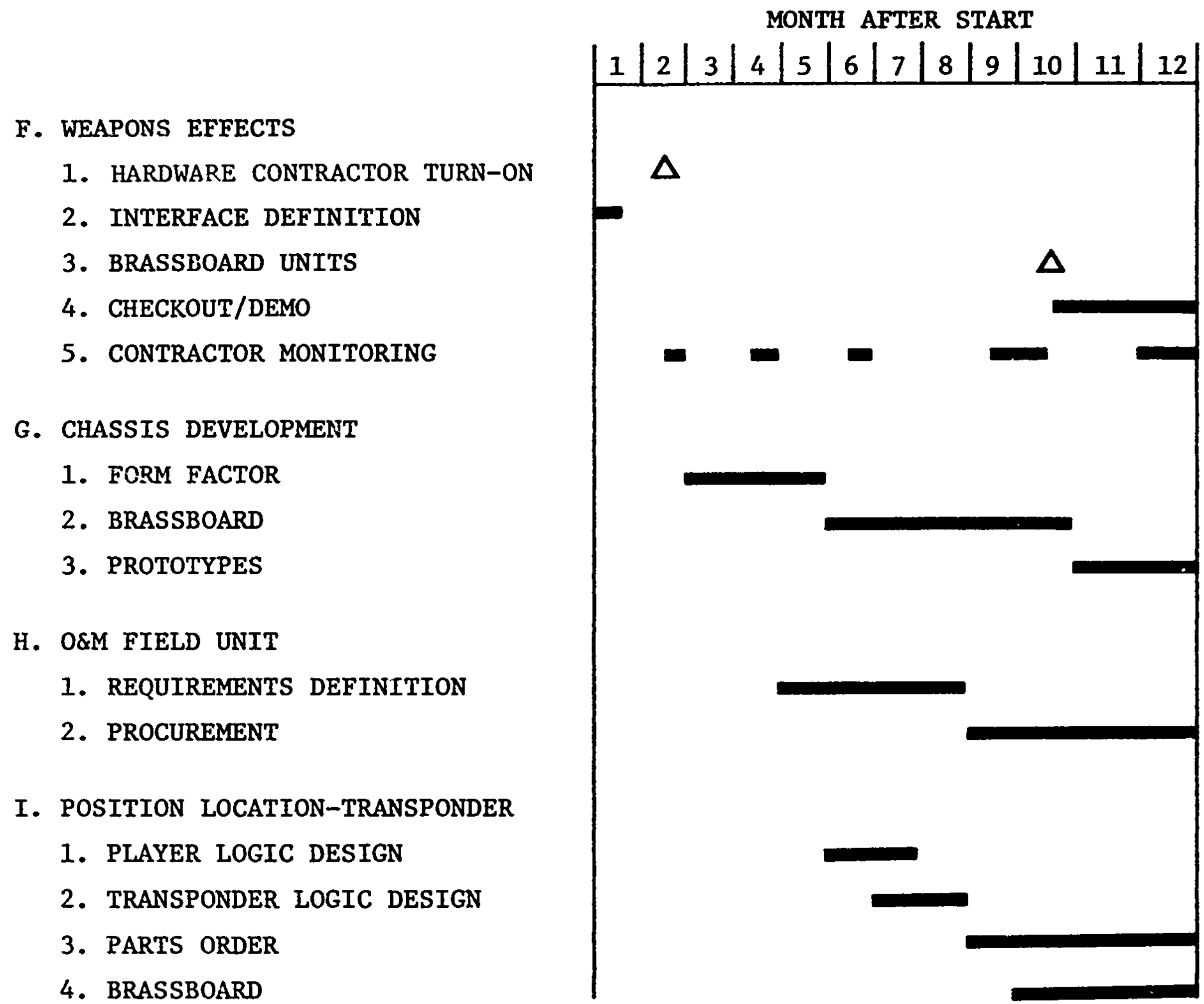


Figure 25. Detailed FY79 development tasks (continued).

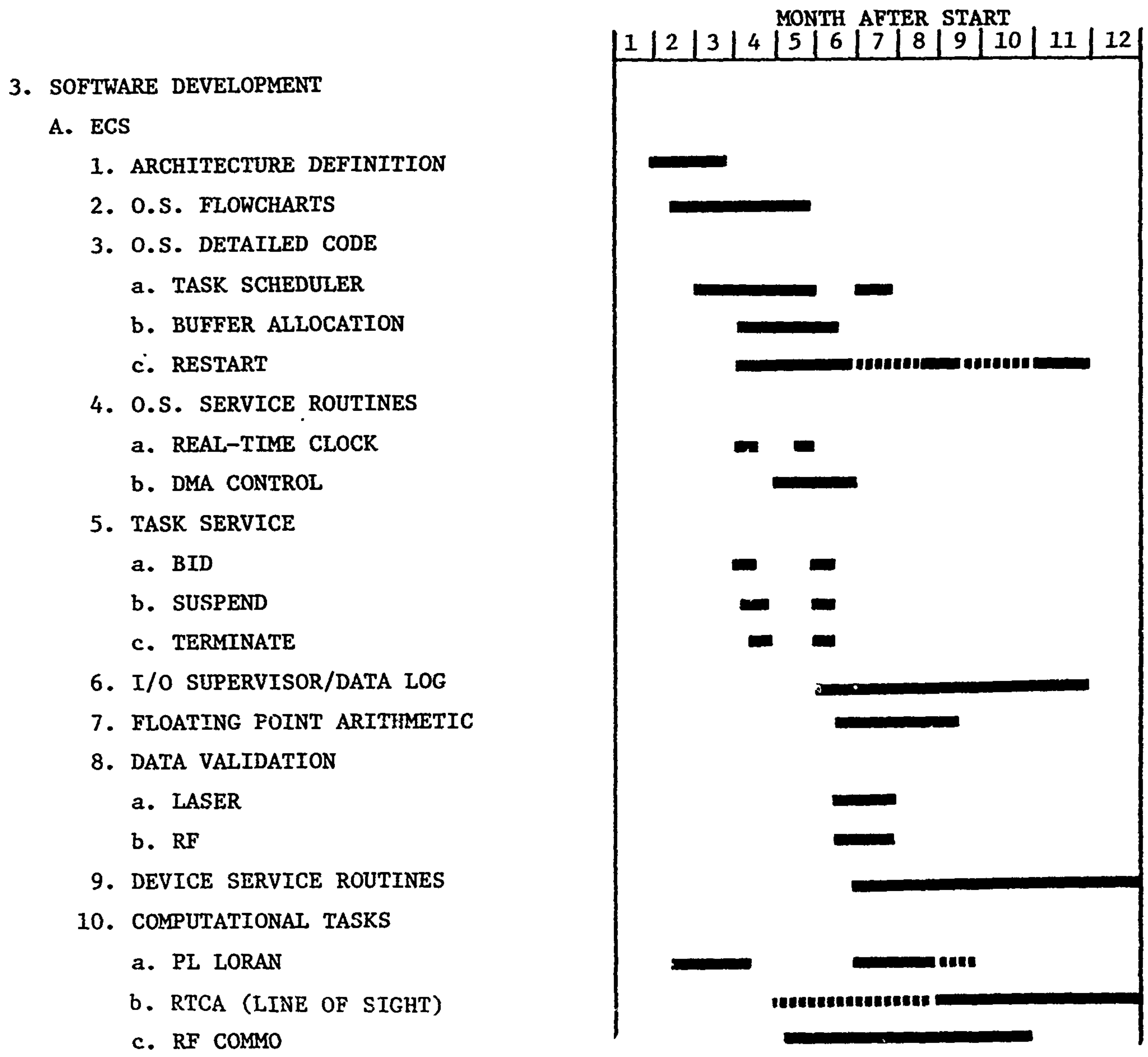


Figure 25. Detailed FY79 development tasks (continued).

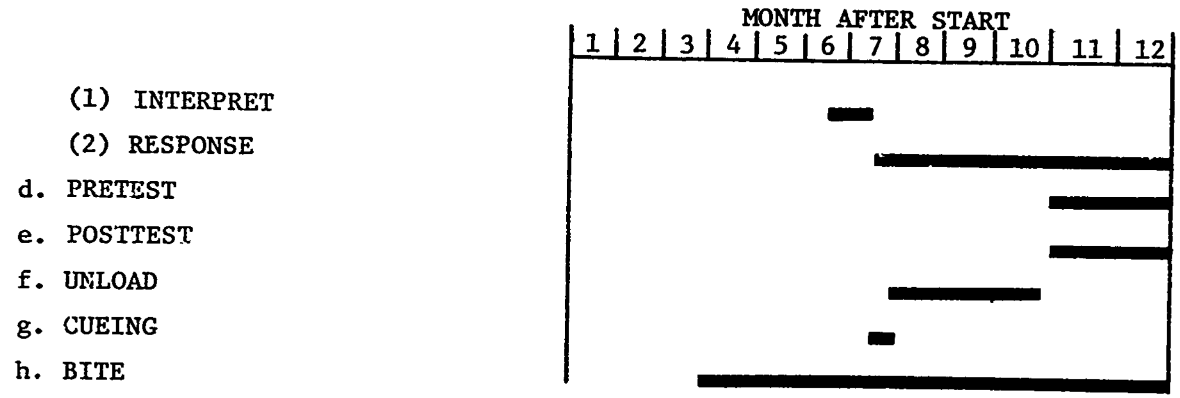


Figure 25. Detailed FY79 development tasks (concluded).

Table 9. Brassboard, prototyping, and preproduction cost estimates.

Item	FY 79 K$	FY 79 UNITS	FY 80 K$	FY 80 UNITS
1. ECS				
Brassboard	12	3		
Prototype	38	15		
Preproduction			130	50
2. LORAN Receivers				
Brassboard	27	2		
Prototype	165	15		
Preproduction			250	50
3. RF Communications				
Brassboard	110	6*		
Prototypes	145	21**		
Preproduction			300	61***
4. Weapons Effects				
Brassboard	225	3		
Prototype	120	15		
Preproduction			500	50
5. Data Log				
Brassboard	6	3		
Prototype	25	15		
Preproduction			85	50
6. Universal I/O				
Brassboard	2	3		
Prototype	7	15		
Preproduction			22	50
7. Chassis Development				
Brassboard	20	3		
Prototype	45	15		
Preproduction			150	50
8. Direct Ranging R&D			96	3
9. Mini Support	8		7	
10. O&M System			175	
11. Equipment Rental	6		7	
12. Travel	31		25	
13. Hardware Development Sup.	91	1		
14. Contingencies	90		100	
	$1173		$1847	

*1 Master Station, 3 Repeaters, 2 Players to be returned to conversion to prototype

**1 Master, 5 Repeaters, 15 Players

***1 Master, 10 Repeaters, 50 Players

4-2.3 Production Cost Estimates.

The cost estimates for production units are tabulated in Table 11. Constant FY 1978 dollars were used for comparison purposes. Breakouts by 50-player full-system, 50-player units, and master and repeater station are provided.

Table 10. Summary of development costs.

	FY 79	FY 80	FY 81
Integration			
Labor	745	457	175
Hardware	165	120	---
GFE Hardware	1008	1727	160
	$1918	$2314	$335

$4567 K or $70.26 K/unit

Table 11. Production cost estimates.

ITEM			K$/UNIT	50-PLAYER FULL SYS*	50-PLAYER UNIT	MASTER AND REPEATERS**
1.	ECS		2.6	130	130	--
2.	a.	Master	6.0	6	--	6
	b.	Transponder/ Repeater	7.0	70	--	70
	c.	Player	5.0	250	250	--
3.	Weapons Effects		9.0	450	450	--
4.	Data Logging		1.25	63	63	--
5.	Universal I/O		0.9	45	45	--
6.	Chassis		3.0	150	150	
7.	Mini/O&M			175	--	175
8.	Field Support Eq.			15	--	15
9.	Loran-C Receivers		5.0	250	250	
10.	Direct Ranging		3.0	150	150	
	Sub Total			1754	1488	266
11.	Spares (10%)			175	149	27
	Total			$1929K	$1637K	$293K
	Per Player Cost			$38.6K	$32.7K	
	Less Loran Per Player Cost			$33.1K	$27.2K	

*Includes 1 Master Station, 10 Repeater/Transponders, 50 Players, and an O&M Facility.

**Includes 1 Master Station, 10 Repeater/Transponders, and an O&M Facility

SECTION 5

REFERENCES

1. Task Directive 77-0004 TSPI, Engineering Design Study,Phase II, BDM/TAC-78-105-TR, for the Tactical Fighter Weapons Center Range Group/ENP, Nellis AFB, Nevada, 9 March 1978.

2. Motorola Tracking System - Precise Position Determination of Multiple Moving Targets, Motorola Corp., Scottsdale, Arizona.

3. Multiple Integrated Laser Engagement System, Xerox Elextro-Optical Systems, Pasadena, California.

4. Final Draft - Simulator System, Firing, Laser: XM-60, For M16A1 Rifle, TM9-6920-370-12-1, Department of the Army Technical Manual, Operator and Organizational Maintenance Manual, 28 April 1978.

5. R. L. Harrington and J. T. Dolloff, "The Inverted Range: GSP User Test Facility," IEEE Position Location and Navigation Symposium, November 1976, pp. 204-211.

6. F156-77, Vega Model 6133 Multi-Vehicle Positioning System, Vega Precision Laboratories, Inc., Vienna, Virginia, 16 August 1977.

7. Loran C-Accurate, Long Range Navigation, Technical Data, Teledyne Systems Co., Northridge, California.

8. Infantry Direct Fire Simulator System, Operation and Preventive Maintenance Manual, Revision A, International Laser Systems, Inc., for the U.S. Army Combat Developments Experimentation Commands, Fort Ord, California, January 1976.

9. Lasers and Electro-Optics Catalogue ID-105C, International Laser Systems, Inc., Orlando, Florida, Special Programs Division, August 1978.

10. D. F. McDonald and R. P. Marchi, Long Range Trends in Instrumented Field Testing and Training, BDM/W-0-78-071-TR, 1 February 1978.

11. "Operation Test Instrumentations Guide," Vol. I-III, Braddock, Dunn, and McDonald, Inc., and RMC Research Corporation, for the U.S. Army Operational Test and Evaluation Agency, January 1974.

12. E. H. Ehling, ed., Range Instrumentation, Prentice-Hall, 1967.

13. GUARD Phase I Report, BDM/TAC-78-30-TR, for the Sandia Laboratories, 30 June 1978.

14. Draft - Final Report of Instrumentation for PARAFOX VII, U.S. Army Combat Development Experimentation Command.

15. R. E. Odom, Indirect/Area Fire Weapons Effect Simulator Study (Summary), TND-TR-76-0002, I and II, International Laser Systems, Inc., January 1977.

16. Final Report - Engineering Services for an Instrumented Range Facility, BDM/M-010-78, for the U.S. Army Aviation Center, 29 September 1978.

17 N. Lawhead, "Position Location Systems Technology," IEEE Position Location and Navigation Symposium, November 1976, pp. 1-12

18. J.A. Kivett, "PLRS - A New Spread Spectrum Position Location Reporting System," IEEE Position Location and Navigation Symposium, November 1976, pp. 223-230.

19. TNF S^2 Issues for EUCOM, BDM/W, 10 March 1978.

20. Final Report - Volume I - Development of Scope for Improving the Survivability and Security of the Theater Nuclear Force, BDM/W-0320-78-S, 9 March 1978.

21. Real Time Casualty Assessment Handbook, Vol. II., Casualty Assessment Parameters, 1 August 1977, BDM Services Company.

22. Algorithms Developed in Phase II of Transporation Safeguards Effectiveness Model, BDM/A-78-094-TR-R1.

23. Soviet Special Operations, Scenarios I and II, BDM/W-0666-78-S, 27 March 1978.

24. Final Report - Soviet REC Threat to the TNF, BDM/W, 13 October 1978.

25. Instrumentation Required Operational Capabilities Programs, U.S. Army Combat Developments Experimental Command, 1 May 1978.

26. NAVSTAR Global Positioning System, Integration Working Group Kick-off Meeting, 16 September 1976.

27. Position Location Reporting System, System Technical Description, Hughes Aircraft Company, General Systems Group, for the U.S. Army Electronic Command, 15 September 1977.

APPENDIX A

GLOSSARY

ACCUFIX	-	Trade name for a dedicated LORAN system.
A/D	-	Analog to Digital. An electronic means of converting a voltage continuous with respect to time into a number represented by a discrete set of voltage states. A continuous voltage is converted into a discrete digital word or number.
AMSAA	-	Army Material Systems Analysis Agency.
APU	-	Arithmetic Processing Unit. Provides floating point arithmetic, trigonometric functions, etc., on a s .gle integrated circuit. Very high speed.
ATGM	-	Antitank Guided Missile. In this report it refers to a class of wire-guided missiles designed specifically for the destruction of armored or heavily fortified targets.
BITE	-	Built-In Test and Evaluation. Self-test circuitry built into an electronics module which allows functional testing of the module during its operation.
BYTE	-	8-bit packet of digital computer data.
CBW	-	Chemical-Biological Warfare.
CIU	-	Communications Interface Unit. A module in the TNF S^2 player pack which handles data conversion for both the laser weapon simulator and RF communications.
CMOS	-	Complementary Metal Oxide Semiconductor. Extremely low-power technology. Only a limited number of functional part types are available. Very slow operation compared to other technologies.
CONUS	-	The area bounded by the Continental United States, including Alaska.
CPU	-	Central Processing Unit. In a microcomputer this refers to the microprocessor component.

CRU	-	Communications Register Unit. A serial data communications channel implementation unique to the SBP9900 family of microprocessors.
D/A	-	Digital to Analog Converter. Converts a digital input word to an output voltage. The magnitude of the voltage is proportional to the binary value of the digital input.
DC/DC	-	A voltage converter that changes an input DC voltage to another, regulated, output voltage. Used to produce regulated ±5, ±12 volt power from unregulated 28V batteries in the TNF S^2 player pack.
DMA	-	Direct Memory Access. The process of transferring information from one area of a computer memory to another without intervention by the CPU. It is orders of magnitude faster than CPU controlled transfers.
DMAC	-	Direct Memory Access Controller. A single integrated circuit which, once initialized by the CPU, controls the DMA process.
DME	-	Distance Measuring Equipment.
ECS	-	Executive Control System. The player pack microcomputer, including hardware and software, exclusive of the functional hardware modules.
EUCOM	-	European Command, Command for U.S. Military Forces in Europe.
FIFO	-	First-In-First-Out Memory. A single integrated circuit memory stack with a capacity of 4 to 64 bytes. Data is entered at a single point and retrieved from a single point in the order of entry.
ID	-	Identification Code. Used to identify players, weapons, and weapon types.
IDF	-	Indirect Fire. Generic term referring to all military weapons except those used in a point-to-point mode, such as rifles. Examples: mortars, artillery, grenades, missiles, etc. Usually with explosive rounds.

I/O	-	Input/Output. Refers to the generic data transfer process. Usually implies communications between a computer and its peripherals.
GPS/NAVSTAR	-	Global Positioning System. A position location system based on the use of synchronous satellites.
HEAT	-	High Explosive Antitank round.
LOS	-	Line of Sight. Refers to weapons which are usually sighted on the target (rifles, etc.).
LRRP	-	Long-Range Reconnaissance Patrol.
LWESS	-	Laser Weapon Engagement Scoring System. Laser weapon simulator produced by International Laser System, Orlando, Florida.
MILES	-	Multiple Integrated Laser Engagement System. A laser weapon simulator system produced by Xerox Corporation.
MOE	-	Measure of Effectiveness.
MTBF	-	Mean Time Between Failures. In an electronic system it is roughly inversely proportional to the number of components.
O&M	-	Operations and Maintenance.
OS	-	Operating System. Computer software which controls allocation of computer resources among competing processes.
OSD/TE	-	Office of the Secretary of Defense/Test and Evaluation.
PL	-	Position Location.
RF	-	Radio Frequency.
RTCA	-	Real-Time Casualty Assessment. A computer algorithm which determines the probability that an engaged player has been killed.
TCATA	-	TRADOC (Training and Doctrine Command, U.S. Army) Combined Arms Test Activity.
TDOA	-	Time Difference of Arrival.
TFWC	-	Tactical Fighter Weapons Center, U.S. Air Force.
TNF	-	Theater Nuclear Force.

TNF S^2	-	Theater Nuclear Force Survivability and Security.
TOW	-	Tracker, Optical Wire. A missile guidance technique which utilizes visual target tracking with correction signal transmission via a trailing wire from the missile.
TSEM	-	Transportation Safeguards Effectiveness Model. A computer model designed to assess the effectiveness of safeguards employed in the transportation of nuclear materials (DOE).
TTL	-	Transistor-Transistor Logic. A logic family characterized by its input/output features. Very commonly used.

APPENDIX B

REQUIRED GOVERNMENT-FURNISHED TEST EQUIPMENT

B-1 RF TEST EQUIPMENT.

This instrumentation is required to support the development, test, and evaluation of several RF modules to be developed under the terms of this contract. The test equipment will enable the performance assessment of the manpack instrumentation system in various RF environments. The effects on communications and position location can be quantified against a solid background of referenced test equipment.

The items required (or equivalents) are given below:

Item	Type	Model	Qty	Measurement Requirement
1	RF Power Meter	HP432A	1	+10dBm to -20dBm 10 MHz-6 GHz
2	RF Power Sensor	HP278A	2	Necessary for operation of 478A
3	Directional Coupler	HP779D	2	-20 ±1dB coupling 1.7-12.4 GHz
4	Crystal Detector	HP423A-003	4	±0.2 dB/octave to 6 GHz
5	50L Load	HP909A	4	VSWR F 1.12 @ 6 GHz
6	Spectrum Analyzer	HP141T 8552B 8555A	1	-60dBm, 10 MHz - 6 GHz
7	RF Sweep Generator	5000A 5011M 5014-13	1	+3dBm Sweep from 1 to 6 GHz
8	Microwave Attenuator Set	HP11581A	1	3, 6, 10, 20 dB Attenuation DC-8 GHz
9	Microwave Attenuator	HP8496A	2	0-110dB step Atten DC-18 GHz
10	Counter/Time Interval Meter	HP5328A	1	Opt 031, 040, 011 Precision Time Interval, Microwave Frequency Counter
11	High Power Attenuator		2	20 dB 100W DC-6 GHz
12	TWT Amplifier	HP489A	1	30 dB +6dB 1-2 GHz
13	TWT Amplifier	HP493A	1	30 dB +6dB 4-8 GHz
14	Power Supply	Regulated V&I	4	30 Volts One Ampere
15	Dual Tracking Power Supply		2	±15 Volts 200mA

B-2 DIGITAL TEST EQUIPMENT.

The list below details a variety of digital test equipment required for the development of the ECS (executive control system) and all of the associated peripheral modules in the player pack. Rapid debugging and decoding of logic states for memory arbitration logic and interface buss development are the hard requirements to be met by the test equipment listed (or equivalent).

Item	Type	Model	Qty	Measurement Required
1	Logic State Analyzer	HP1615A	1	5nS glitch detection Trace Analysis, 24 bits wide, a synchronous trace 256 word memory
2	Logic Analyzer Biomation	K100D	1	32 bits x 1024 word capture, Assembler Definition storage, 1024 word reference comparison memory
3	Signature Analyzer	HP5004A	2	Digital Node Signature Analysis Field Troubleshooting
4	Logic Probe Kits	HP5015T	2	Logic Probe, Logic Pulser, Logic Clip
5	Digital Current Tracer	HP547A	2	Detect Logic failure in the Latched-Low state.
6	Power Supply Regulated	0.1%	4	0-6v 4 Amp
7	Power Supply Regulated	0.1%	4	0-6v 1 Amp
8	Power Supply	0.1%	4	0-15v 500 mA

B-3 AUDIO TEST EQUIPMENT.

This equipment is needed for use in the development of TNF S^2 instrumentation associated with every category of weapon simulation. The definition and development of instrumentation to perform on-player RTCA requires adequate test equipment. Acoustic phenomena are related to direct-fire short-range measurement, five categories of cueing, and indirect fire real-time casualty assessment.

The items (or equivalent) that are required for this work are listed below:

Item	Type	Model	Qty	Measurement Required
1	Function Generator	HP3312A	2	Triggered Burst Waveforms/ 10 Hz to 1 MHz
2	Counter/Timer	HP5300A	2	Counter Time Interval DC-10 MHz
3	Transducer-Driver Fivasonics	G100	1	Constant power level to varying load

4	General-Purpose Amplifier	HP3582	2	5 Hz-100 KHz Amplifier 24-40 dB
5	Real-Time Analyzer	HP3582	1	DC-25 KHz Dual Channel Spectrum Transfer Function Display
6	Real-Time Analyzer	HP3580	1	DC-50 KHz Single Channel
7	Digital Multimeter	7003	2	DC/AC/ohms/current
8	Power Supply Dual Voltage Tracking		2	±15 volts 200mA
9	Power Supply		2	0-100 volts 100mA
10	Power Supply		2	0-6v 1 Amp

APPENDIX C

LORAN-C FEASIBILITY EVALUATION

During the latter part of July, two Teledyne T1-708 Loran-C receivers were obtaned from the manufacturer and installed in a van in order to evaluate the utility of the Loran-C regional navigation system in free play force-on-force testing. This appendix records the activities following receipt of the equipment and some conclusions concerning the applicability of Loran-C to OTE, as summarized below:

1. Repeatability of an individual Loran-C reading was found to be 17 m.
2. Mean absolute interplayer slant range error was found to be 50 m.
3. No error data as a function of speed was taken but such data from another study shows a contribution of approximately 10 m to existing static error at 64 km/h.
4. No error data as a function of anomaly was isolated.

Loran-C using publicly available transmissions, is useful for calculating interplayer slant range. The data from Ft. Hunter Liggett indicates a one-sigma error of 25 m as the limit to which slant range may be predicted. Local mapping of Loran coordinates will be required to achieve this. The requirement for mapping will have consequences in computer storage requirements and computational speeds required.

The primary objective of the test was to determine how accurate interplayer slant range could be measured with a representative, commercially available Loran receiver. Nine accurately known locations (RMS A-station sites at Ft. Hunter Liggett) were used for this purpose. The two time delays required to calculate location were recorded ten times at each location for each receiver. Each pair of time delays was reduced to a location in UTM coordinates by means of a Fortran subroutine called LORGRD. This routine is based on an algebraic solution for a flat earth. Mean absolute interposition error was found to be 50 m.

Repeatability, the variability in an individual position measurement, was found to be 17 m. These results are for the "A" receiver, which averaged time delays over 12.8 seconds. The "S" receiver, which averaged time delays over 1.6 seconds, did not do nearly as well. However, the "S" receiver was used with an antenna which had been broken in transit and the variability of its time delays may have been due to the mended antenna no longer being matched to the antenna coupler.

Equipment used consisted of two legs of the West Coast Loran-C chain, and two van-mounted Teledyne Loran-C receivers. The West Coast (9940) Loran-C chain has a master station at Fallon, NV, the X station is at Middletown, CA, and the Y station is at Searchlight, NV. The group repetition interval is 99400 microseconds and the time offsets are 27 milliseconds and 40 milliseconds respectively. The chain is automatically monitored and controlled. Chain command is in a facility at Middletown, CA. Two monitors are located at Pt. Pinos, CA (near Monterey) and on the northern Oregon coast, respectively. The stations function unattended, but technicians are avilable within 10 to 15 minutes of an alarm and senior technical advice is available from chain command at all times. The chain has been in operation for approximately 18 months and is presently exhibiting a MTBF of 21 days and an availability of better than 99.8 percent. Stability of the chain is presently on the order of eight feet, undiluted.

The receivers used were TI-708 receivers with the standard antenna coupler and eight foot mast. One receiver, called "A", averaged over 128 group repetition intervals (GRI), or 12.8 seconds, and then displayed the result. The second unit "S", averaged over 16 GRI. "S" gave significantly poorer results than "A" but one of the masts had been broken in transit and had to be splinted and taped. The broken mast was used on "S."

APPENDIX D
RUBIDIUM FREQUENCY STANDARD EVALUATION

During the month of August, two EFRATOM model FRK rubidium frequency standards were evaluated as to their utility as components in a position location system. This appendix records the activities conducted and some of the conclusions reached concerning their applicability to the TNF S^2 program.

Basically, three tests were performed on the standards. These tests were: (1) the Relative Frequency Drift Test, where the relative frequency drift between the two standards was recorded versus time, (2) the Environmental Test, where the effects on the standards due to electromagnetic impulses and fields was seen, and (3) the Position Location Test, where the feasibility of using rubidium standards as mobile and stable time references was investigated.

D-1 RELATIVE FREQUENCY DRIFT TEST.

This was a long-term evaluation of the relative drift between the two rubidium frequency standards. One of the two standards was used as reference (standard "B"), since no other 10-MHz reference frequency standard was available. This standard was equipped with a decade resistor connected in parallel with the 500-ohm resistor, to facilitate minor frequency adjustments.

Both rubidium frequency standards were enclosed to make the standards less susceptible to abrupt ambient temperature changes. Three-quarter-inch perforations allowed the escape of heat, while deflecting sudden minor ambient changes due to personnel activity.

The 10-MHz sine wave outputs from both rubidium standards were connected to an HP-8405 vector voltmeter and were recorded on an HP-7046 X-Y recorder versus time.

D-2 ENVIRONMENTAL TEST.

In the environmental test, the sensitivity of the standards to electromagnetic fields was investigated. The same basic setup was used as in the relative frequency drift test. The standard without the decade resistor connected (standard "A) was put inside a 10-turn loop of wire approximately 20 cm in diameter. This loop was oriented in two planes, so that when current was flowing in the loop, the magnetic field produced was either perpendicular to or parallel with the internal field of the resonator assembly.

D-3 POSITION LOCATION TEST.

In the position location test, the rubidium standards were used as stable time references. Before the actual test, the standards were synchronized so that no detectable drift was present. The stable 10-MHz sine wave output from each standard was divided by 4000 and shaped into a 150-nanosecond pulse occurring every 400-microsecond by a 4K divider and pulse-shaping circuit.

One of the standards was made portable by using a 32-volt battery pack as supply. The 2.5-KHz pulses produced by the 4K divider and pulse-shaper were fed to a Vega 302C-2 transponder modified as a transmitter. The transponder pulse modulated its carrier of approximately 5.6 GHz with the 2.5-KHz pulses. The transponder was equipped with an omnidirectional wide-band antenna. Another Vega 302C-2 transponder was modified to receive a 5.6-GHz carrier and demodulate the 2500 pulses per second, which were then fed into an HP5325 time-interval meter.

The time-interval meter measured the time delay between the transmitted pulses and the pulses from a stationary standard. As the portable transmitter and standard were moved away from the receiver, the time delay increased. The transmitter was moved to several surveyed locations, and a comparison was made between the actual distance and the time delay achieved through RF transmission.

D-4 CONCLUSIONS.

The standard frequency drifts relative to each other exhibited discrete characteristics. That is, either the two oscillators tracked in phase to a few parts in 10^{-14}, or they had frequency differences of parts in 10^{-12} or worse. The specified temperature coefficient values, in parts of drift per degree, were not exceeded. The standards were able to maintain a frequency difference in parts in 10^{-14} over several hours in a benign laboratory environment. This capability, if made possible in a more severe environment while retaining the present characteristics of the standards, could have a variety of applications.

The standards are susceptible to direct-current fields which are parallel to the internal cavity field. An alternating-current field affected the standard only when parallel and at high repetition rates.

Additional development is required to solve the drift rate problem and temperature variations together with reducing overall size and power consumption if these devices are to be used as portable position location devices.

APPENDIX E
INSTRUMENTATION DEVELOPMENT SYSTEM

This appendix describes the instrumentation development system required for engineering development of the TNF S^2 field test instrumentation system. Subsequent to prototype development, this development system shall be fielded as an integral part of the operational test control and field maintenance portion of the total field test instrumentation system. The man-pack instrumentation is based on an SBP9900 controller. For purposes of maintainability and reduced operational costs, it is imperative that the operational test control unit and the man-pack controller be machine-code compatible. This requires the prototype development system to execute precisely the same binary machine instructions as the man-pack controller and at full speed.

To reduce both development time and cost, the prototype development system must provide simultaneous service to at least two in-circuit emulators for prototype debugging and verification. Furthermore, it must provide simultaneous access to common system resources to at least two additional users. The in-circuit emulators must provide real-time, interactive, hardware/software state trace and breakpoint features.

There are only two candidate prototype development systems available for the SBP9900. The first is from Tektronix. It supports only a single in-circuit emulator and cannot be expanded. Further, it can never support more than one user at a time. Its capabilities are limited solely to prototype development and it would be totally impossible to field the unit for test control and maintenance. The second system is produced by Texas Instruments. It will support up to 64 simultaneous users, 14 of which may be in-circuit emulators. The machine code used by the TI system is precisely that used by the SBP9900. Furthermore, the unit is ideally suited for fielding as a part of the complete instrumentation system.

There is only one manufacturer of a development system that meets the requirements set forth in this document. That system is the DS990-AMPL prototyping Lab produced by Texas Instruments, shown in Figure 26.

It is known that such a system is available and uncommitted at TI for the month of November. Failure to successfully acquire this system will result in a delivery schedule of 90 to 120 days ARO minimum. Such a delay would have a severe negative impact on the program.

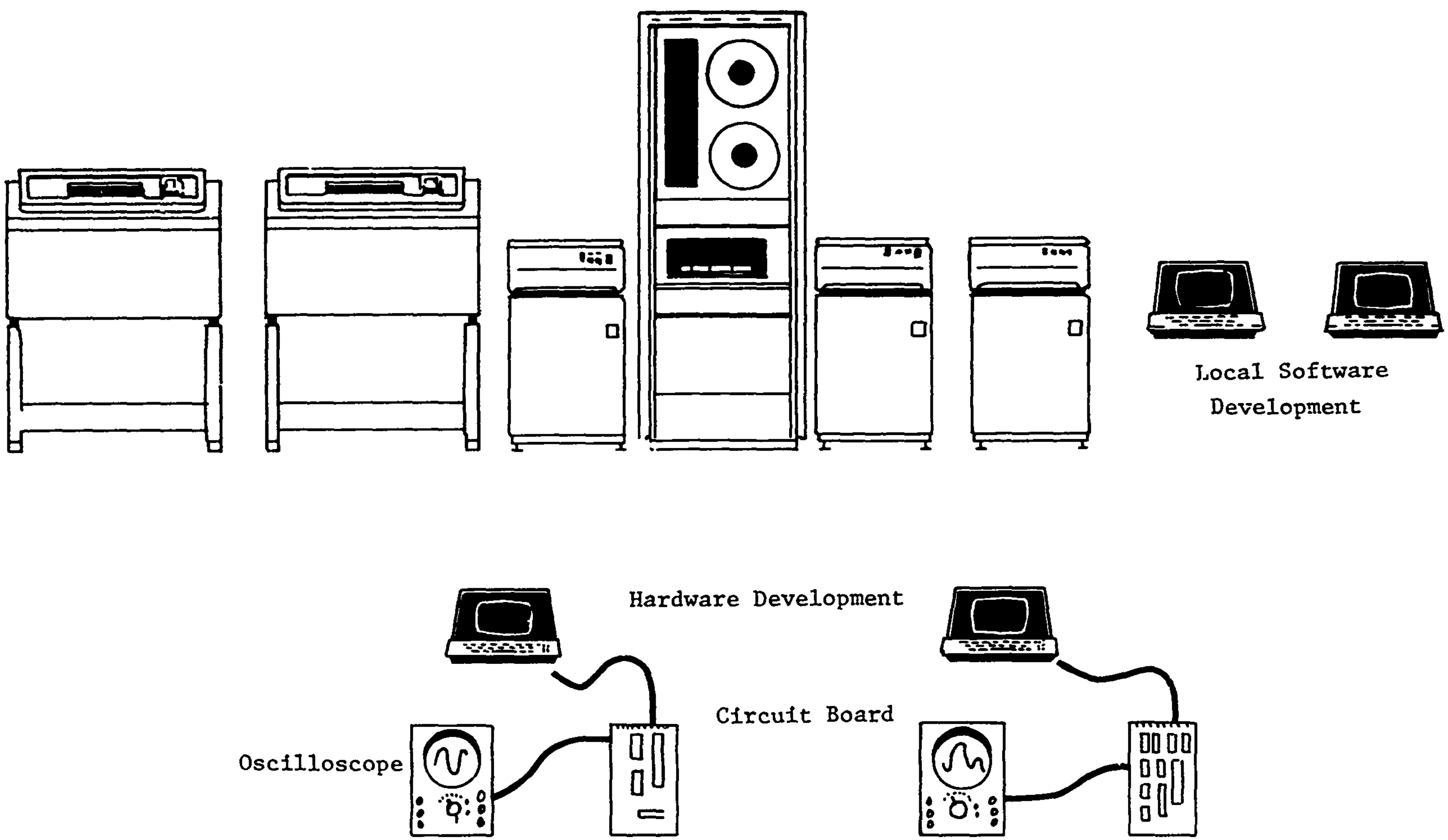


Figure 26. Hardware development system.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

AFSOUTH
ATTN: U.S. Documents Officer

Armed Forces Staff College
ATTN: Reference & Technical Services Branch

Assistant Secretary of Defense
International Security Affairs
ATTN: P & P Nuclear Policy
ATTN: Policy Plans & NSC Affairs
ATTN: NATO Nuc Policy Div
ATTN: European & NATO Affairs

Assistant Secretary of Defense
Comm, Cmd, Cont & Intell
ATTN: Surveillance & Warning System
ATTN: Combat Support
ATTN: Intelligence Systems

Assistant Secretary of Defense
Program Analysis & Evaluation
ATTN: General Purpose Programs
ATTN: Strategic Programs
ATTN: Regional Programs

Assistant to the Secretary of Defense
Atomic Energy
ATTN: Executive Assistant

Command & Control Technical Center
ATTN: C331/NCPS

Commander in Chief
U.S. European Command
ATTN: J-5
ATTN: J-2-ITD
ATTN: J-5NPG
ATTN: J-3
ATTN: J-2
ATTN: J-417-LW
ATTN: J-6

Commander in Chief, Pacific
ATTN: J-2
ATTN: J-54
ATTN: J-3
ATTN: J-6

Defense Advanced Rsch Proj Agency
ATTN: TTO

Defense Communications Agency
ATTN: Director

Defense Communications Engineer Center
ATTN: R-123

Defense Intelligence Agency
ATTN: RDS-3C
ATTN: DT-1

Defense Technical Information Center
12 cy ATTN: DD

DEPARTMENT OF DEFENSE (Continued)

Defense Nuclear Agency
ATTN: OASO
ATTN: STSS
4 cy ATTN: TITL

Field Command
Defense Nuclear Agency
ATTN: FCC-FCRRK
ATTN: FCP-FCPRT

Field Command
Defense Nuclear Agency
Livermore Division
ATTN: FCPRL

Field Command
Defense Nuclear Agency
ATTN: FCPRA

Intelligence Center, Pacific
ATTN: I-3

Interservice Nuclear Weapons School
ATTN: TTV 3416th TTSQ

Joint Chiefs of Staff
ATTN: J-5 Nuclear Division
ATTN: SAGA
ATTN: J-3

Joint Strat Tgt Planning Staff
ATTN: JP
ATTN: JL

Secretary of Defense Representative
Mutual & Balanced Force Reduction
ATTN: R. Clarke

National Defense University
ATTN: NWCLB-CR

Director, Net Assessment
ATTN: DIR, A. Marshall

Commander
U.S. Forces Korea
ATTN: DJ-AM-SM
ATTN: CJ-P-G

U.S. National Military Representative
SHAPE
ATTN: U.S. Documents Officer for Ops
(Nuc Plans)

Undersecretary of Def for Rsch & Engrg
ATTN: Strategic & Space Systems (OS)

DEPARTMENT OF THE ARMY

Deputy Undersecretary of the Army
ATTN: Mr. Lester (Operations Research)

DEPARTMENT OF THE ARMY (Continued)

Deputy Chief of Staff for Ops & Plans
Department OF THE Army
ATTN: DAMO-RQS
ATTN: DAMO-SSP
ATTN: DAMO-SSN, LTC Cooper
ATTN: DAMO-SSW
ATTN: DAMO-NCC, V. Fenwick
ATTN: DAMO-ZD, C. Williams

Deputy Chief of Staff for Rsch Dev & Acq
Department of the Army
ATTN: Advisor for RDA Analysis, M. Gale
ATTN: DAMA-CSS-N, W. Murray
ATTN: DAMA-CSM-N

Electronics Tech & Devices Lab
U.S. Army Electronics R&D Command
ATTN: DELEW, R. Freiberg

Harry Diamond Laboratories
Department of the Army
ATTN: DELHD-N-RBA, J. Rosado
ATTN: DELHD-N-CO, J. Ramsden
ATTN: DELHD-N-TD, W. Carter
ATTN: DELHD-N-P, F. Balicki

Measurement ECM & Support Technical Area
Department of the Army
ATTN: DRSEL-WL-M-M

Office of the Chief of Staff
Department of the Army
ATTN: DACS-DMO

U.S. Army Air Defense School
ATTN: ATSA-CD-SC

U.S. Army Armament Research & Development Command
ATTN: DRDAR-LCN-E

U.S. Army Ballistic Research Labs
ATTN: DRDAR-BLV

U.S. Army Comb Arms Combat Dev Acty
ATTN: AT 2LCA-DLT

U.S. Army Concepts Analysis Agency
ATTN: CSCA-WGG

U.S. Army Elct Warfare Lab (Ecom)
Missile Electronic Warfare Tech Area
ATTN: DELEW-M-FM, S. Megeath

Commander in Chief
U.S. Army Europe and Seventh Army
ATTN: DCSOPS-AEAGB
ATTN: DCSOPS-AEAGC-O-N
ATTN: DCSOPS-AEAGD-MM

U.S. Army Forces Command
ATTN: AFOP-COE

U.S. Army Materiel Dev & Readiness Cmd
ATTN: DRCDE-DM

DEPARTMENT OF THE ARMY (Continued)

U.S. Army Materiel Sys Analysis Activity
ATTN: DRXSY-DS
ATTN: DRXSY-S

U.S. Army Missile Command
ATTN: DRSMI-YDR, Foreign Intelligence Office

U.S. Army Nuclear & Chemical Agency
ATTN: Library for MONA-ZB
ATTN: Library for MONA-SAL

U.S. ARMY Ordnance & Chemical Center and School
ATTN: ATSL-CCC-M

U.S. Army TRADOC Systems Analysis Activity
ATTN: ATAA-TDC, J. Hesse

U.S. Army Training and Docctrine Comd
ATTN: ATORI-IT-TA

U.S. Army War College
ATTN: AWCI, R. Rogan

V Corps
Department of the Army
ATTN: AETVFAS-F, P. Reavill

VII Corps
Department of the Army
ATTN: AETSFA-FSE
ATTN: AETSGB-I
ATTN: AETSGB-O
ATTN: AETSGC-O

Army Research Institute
ATTN: R. Sulzen

DEPARTMENT OF THE NAVY

David Taylor Naval Ship R & D Ctr
ATTN: Code 174/Code 186

Naval Academy
ATTN: Nimitz Library/Technical Rpts Branch

Naval Material Command
ATTN: MAT-OON

Naval Ocean Systems Center
ATTN: Research Library

Naval Postgraduate School
ATTN: Code 1424, Library

Naval Research Laboratory
ATTN: Code 4108

Naval Surface Weapons Center
ATTN: Code F31
ATTN: Code F32, W. Emberson
ATTN: Code X211

Naval War College
ATTN: Center for War Gaming
ATTN: 12

DEPARTMENT OF THE NAVY (Continued)

Naval Weapons Center
ATTN: Code 31707

Naval Weapons Evaluation Facility
ATTN: Code AT

Nuclear Weapons Tng Group, Atlantic
Department of the Navy
ATTN: Technical Library

Office of Naval Research
ATTN: Code 713

Office of the Chief of Naval Operations
ATTN: OP 604

Plans Division
Plans & Policies Department
Headquarters Marine Corps
ATTN: Code PL for Joint Strategic Branch

Commander-in Chief
U.S. Atlantic Fleet
Department of the Navy
ATTN: Code J-34
ATTN: Code J-54

Commander-in-Chief
U.S. Naval Forces, Europe
ATTN: N326, R. Thomas

DEPARTMENT OF THE AIR FORCE

Aeronautical Systems Division
Air Force Systems Command
ATTN: XRO/MAR, J. Sherrod

Aerospace Defense Command
ATTN: ADCOM/INA

Air Force Armament Laboratory
ATTN: AFATL/DLY

Air Force Weapons Laboratory
Air Force Systems Command
ATTN: SUL
ATTN: NSSB
ATTN: AFWL SA
ATTN: NTN

Assistant Chief of Staff
Studies & Analyses
Department of the Air Force
ATTN: AF/SAMI

Operations Plans and Readiness
Department of the Air Force
ATTN: AFXOXF, R. Linhard
ATTN: AFXOXFM

Research, Development. & Acq
Department of the Air Force
ATTN: AFRDQSM

DEPARTMENT OF THE AIR FORCE (Continued)

Tactical Air Command
Department of the Air Force
ATTN: XPS
ATTN: XPSC
ATTN: DRA

U.S. Air Forces in Europe
ATTN: XPXX
ATTN: INAT
ATTN: XPX

DEPARTMENT OF ENERGY

Department of Energy
ATTN: OMA, D. Hoover

Department of Energy
ATTN: DOE/ISA

DEPARTMENT OF ENERGY CONTRACTORS

Lawrence Livermore National Laboratory
ATTN: L-9, R. Barker
ATTN: L-9, D. Blumenthal
ATTN: L-21, M. Gustavson

Los Alamos National Scientific Laboratory
ATTN: G. Best

Sandia National Laboratories
ATTN: J. Kaizur
ATTN: Sys Studies Div 1313
ATTN: 1313, T. Edrington

DEPARTMENT OF DEFENSE CONTRACTORS

Advanced Research & Applications Corp.
ATTN: R. Armistead

AVCO Research & Systems Group
ATTN: G. Grant
ATTN: J. Gilmore

Battelle Memorial Institute
ATTN: D. Hamman

BDM Corp.
ATTN: J. Braddock

BDM Corp.
ATTN: T. McWilliams

General Electric Company-TEMPO
ATTN: DASIAC

General Research Corp.
ATTN: H. Schroeder
ATTN: P. Lowry

Hudson Institute, Inc.
ATTN: H. Kahn

Hughes Aircraft Co.
ATTN: H. Ward

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

JAYCOR
ATTN: E. Almquist
ATTN: R. Sullivan

JAYCOR
ATTN: S. Brucker

Kaman Sciences Corp.
ATTN: F. Shelton

LFE Corp.
ATTN: M. Nathans

Lockheed-California Co.
ATTN: G. Busch

Mathematical Applications Group, Inc.
ATTN: M. Cohen

Mission Research Corp.
ATTN: D. Sowle

R & D Associates
ATTN: C. MacDonald
ATTN: S. Cohen
ATTN: A. Latter
ATTN: P. Haas

R & D Associates
ATTN: R. Latter

Rand Corp.
ATTN: W. Jones
ATTN: Library

Santa Fe Corp.
ATTN: D. Paolucci

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Science Applications, Inc.
ATTN: J. Martin
ATTN: M. Drake

Science Applications, Inc.
ATTN: W. Layson

SRI International
ATTN: D. Elliott
ATTN: P. Dolan

SRI International
ATTN: R. Foster
ATTN: W. Berning

Systems, Science & Software, Inc.
ATTN: K. Pyatt

Systems, Science & Software, Inc.
ATTN: J. Cane

Technology Service Corp.
ATTN: S. Canby

Tetra Tech, Inc.
ATTN: F. Bothwell

TRW Defense & Space Sys Group
ATTN: N. Lipner

TRW Defense & Space Sys Group
ATTN: P. Dai

Vector Research, Inc.
ATTN: S. Bonder

American Institute for Research
ATTN: E. Johnson